METALLURGIA

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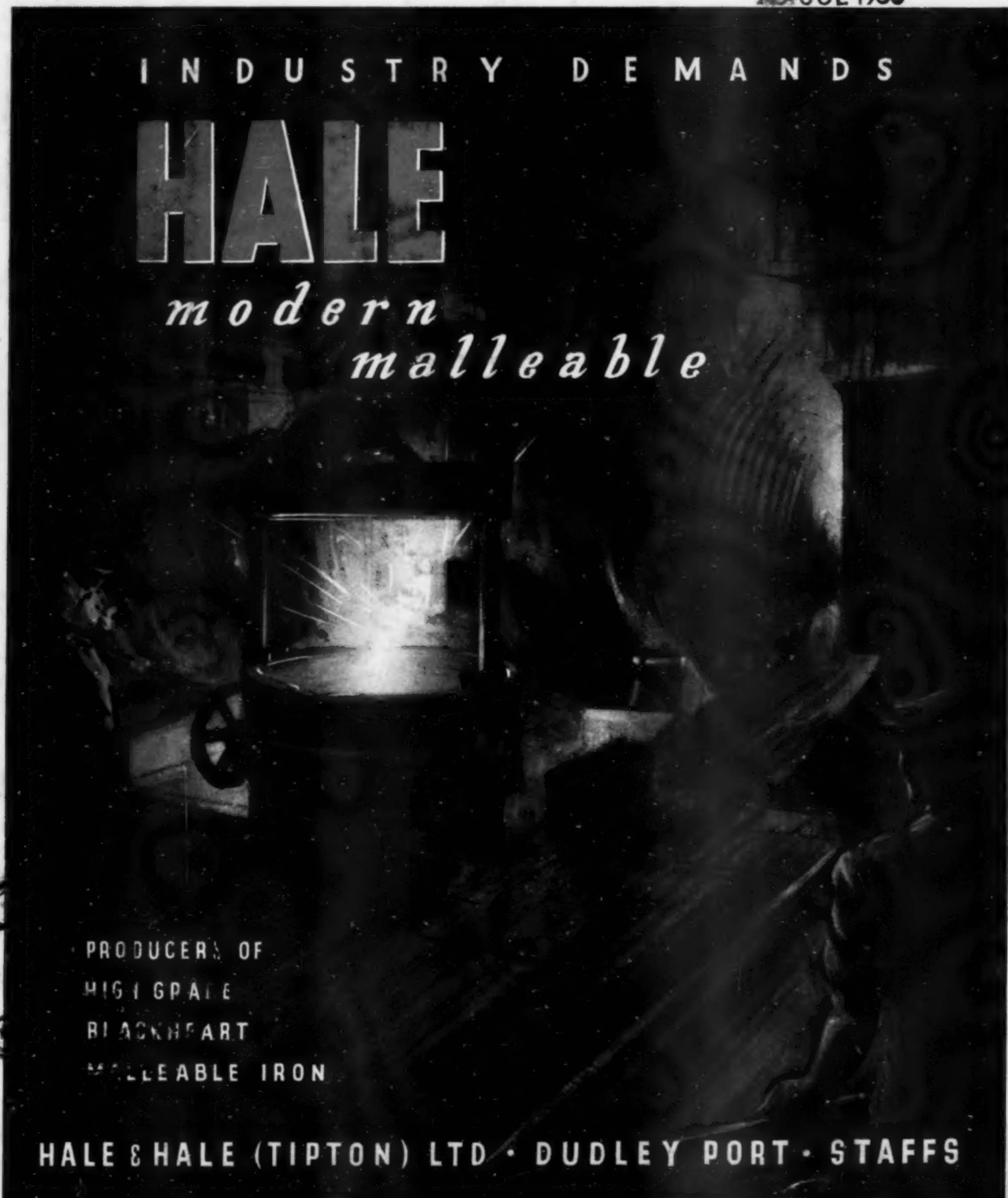

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METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

CONTENTS FOR JULY, 1953 Vol. 48 No. 285

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LABORATORY METHODS SUPPLEMENT

The articles in this Journal are indexed in THE INDUSTRIAL ARTS INDEX

METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

JULY, 1953 Vol. XLVIII. No. 285

Science and Craftsmanship

OF no other branch of metallurgy is it more true to say that science and craftsmanship go hand in hand than it is of foundry work. It was appropriate, therefore, that Mr. E. Longden, the new President of the Institute of British Foundrymen, should choose as the title of his Presidential Address, "Science, Technology and Craftsmanship," and as, to a greater or lesser degree, practical experience and scientific theory are together aiding progress in other metallurgical fields, we propose to present some of the points Mr. Longden raised.

Not unnaturally, there is a tendency for productive workers, particularly in those industries which call for a considerable amount of skill and craftsmanship in the operatives, to view with suspicion the intrusion of the scientist with his slide rule, his test tubes and his microscope. As Mr. Longden pointed out: There is a great accumulation of scientific knowledge, much of which is not being used correctly, if at all, by the operative craftsman. On the other hand, there is a failure on the part of some scientists to understand production procedure and the parochial-mindedness of workers. It is necessary for the scientist and technologist to teach and elaborate understanding of that which is inefficiently practised, with a view to its improvement, and also that which is new in knowledge and discovery.

The division between pure and applied science is a somewhat arbitrary one, and in the same way there seems to be no clear dividing line between the industrial scientist and the technologist, or between the technologist and craftsman. The improvement of craftsmanship depends, to a large extent, on its ability to absorb scientific and technological discoveries, mechanical developments and a willingness to accept a scientific organisation of production. Thus a combination of experience, technology and science is the key to continued improvement in production and productivity, which is the fountain of all material wealth and well-being for all. A new class of skilled worker is being developed—what one might call the scientifically skilled worker. Science may be described as the systematic study of demonstrable facts relating to the material world. Such facts fit in with definite laws which direct and control operations, and craftsmanship cannot, therefore, effectively function without actually putting into practice certain scientific principles. Hence, if the craftsman can be made more aware of his dependence on science, there is greater hope for increased co-operation between craftsman and scientist.

The urgent need for self-preservation and a better standard of living has caused the craftsman to turn for help to scientific principles, and in this, craftsmanship and science have grown in stature. The most successful foundries have based their activities on scientific research and technical endeavour, and have adapted themselves to new sources of knowledge.

After referring to the excellent work of the Institute's Technical Council, which with its sub-committees has issued a great deal of reliable foundry technical literature, based on the investigations and experience of technological experts, Mr. Longden put forward a plea for some degree of unification of foundry research and technology. There might, for instance, be a Parent Research Organisation of Cast Metals, whose object would be a unification of research into the *common* problems of cast metals and their economic fashioning into castings. There has always appeared to be a common basis of approach from the research level, through its technological interpretation, right down to its application at production levels, for all cast metals. As far as the technical and scientific leaders of the industry are concerned, it is difficult to agree that excessive specialisation is conducive to the achievement of the best all-round results in practice. For instance, a fully qualified foundry metallurgist should have a reasonable general knowledge of the origin and production of all metals, and a specialised knowledge of cast metals and their behaviour when poured into moulds of various kinds. It is true that a man may spend his whole life in the study of a single problem without arriving at a satisfactory solution to it, but there are so many obvious similarities and so many common denominators in cast metals, that it would appear that unified studies are desirable.

A similar argument may be applied to the craftsman moulder: there are so many common factors in the construction of moulds that it has always been a source of wonder that there should be such opposition on the part of so many craftsmen to being asked to work with a metal other than that to which they are accustomed. The industry has so often been short of labour on the ferrous side when, at the same time, the non-ferrous side has been short of orders for castings. A general knowledge of the gating and feeding of all cast metals should form part of the basis of apprentice training and the qualifications of foundry leaders should include this general knowledge. The design and volume of liquid-shrinkage feeder gates and heads for steel, malleable iron, aluminium bronze and light alloys are somewhat similar and their mutual study would be helpful.

It is a significant fact that, in the U.S.A., where productivity, measured in output per man-hour, continues to increase, the proportion of scientists and technologists in industry is also increasing: science and technology are, it seems, the pathfinders to industrial efficiency. Industrial research and scientific management have paid high dividends, and normally unprogressive firms have been compelled to interest themselves in research in order to keep up with their naturally research-minded competitors. In this way a leavening of scientific thought is being spread throughout industry.

BISRA Annual General Meeting

Chairman's Statement

At B.I.S.R.A.'s Annual General Meeting, at the Association's Sheffield laboratories on June 17th, the Chairman's address included the announcement that Sir Andrew McCance, F.R.S., had retired from the Presidency, and that Lord Dudley Gordon, D.S.O., had consented to become the new President. After a warm tribute to Sir Andrew's services the statement went on :

"This is the 10th Annual General Meeting of the Association but it is the first that has been held outside London. To-day, we are able to see in Sheffield something of the results of a plan formulated in 1947, when the Council decided to acquire a site and to build laboratories in this city which, together with the B.I.S.R.A. laboratories elsewhere would provide our scientists with the facilities for the considerable research programme that the Association had ahead of it. These laboratories in Sheffield will provide benefits not only for members of the Association in the district, but for the industry as a whole, by which the Association is so well supported.

The first laboratory, erected on this site during 1948, is intended to be a temporary building to be replaced eventually by permanent buildings. Meanwhile, we have taken over further premises on the site, and now we are nearing the end of the first part of our permanent development. The new laboratories will soon be finished and will be opened on November 19th of this year. On that occasion we shall be inviting our Members and our many friends and associates within and beyond our industry to attend the ceremony and to see the laboratories and the plant and research apparatus with which they will be equipped.

It will perhaps be appropriate at this stage to recall that this development was made possible by the generous special grants from the iron and steel industry and from the Government through the Department of Scientific and Industrial Research. The British Iron and Steel Federation on behalf of the industry contributed £160,000 and the D.S.I.R. £80,000. The remainder of the cost of this development will be met from the Association's own resources. I would like also, at this point, to express our appreciation of the assistance given in a number of ways by the Sheffield Corporation and its officials, of the professional skill of our consulting engineers, Messrs. Husband & Co., of the work of the principal contractors, Messrs. George Longdon & Sons, Ltd., and of the untiring efforts of our own staff upon whose shoulders has fallen much of the back-room planning which plays such an important part in any development of this kind.

It is not only at Sheffield that our laboratory facilities have enlarged. At Battersea we have recently completed some improvements of the premises we acquired in 1951 which has enabled the Plant Engineering Division and the Corrosion Laboratory and, to a lesser extent, the Physics and Chemistry Departments to have better and larger working areas. I should at this point inform you that the Head of the Physics Department, Mr. M. W. Thring, will become Professor of Fuel Technology at Sheffield University, when Professor Sarjant, a Member of our Council, retires from the Chair in September of this year. Mr. Thring is to be congratulated on his appointment which is indeed a worthy tribute to his knowledge and ability in the field of fuel technology. I am sure that you will wish me to thank Mr. Thring for his valuable services and to express the hope that there will be many fruitful connections between him and the Association in the near future.

Our Director, Sir Charles Goodeve, has been appointed a Member of the Lord President's Advisory Council on Scientific Policy, the senior body in this country concerned with scientific research in all fields except military.

I will now turn to one or two developments of interest since the Annual Report was published. It will be generally known that the United States has, under the Mutual Security Act, allotted dollar funds to the United Kingdom, the sterling counterpart of which will be spent through approved organisations in the United Kingdom on the extension of research into factors affecting the efficiency or the economy of British industry and advisory technical services. The Association has submitted proposals through the D.S.I.R. for projects which it is hoped will qualify for financial support from this source.

The application of research results from the laboratory by industry is a subject of vital and constant attention of the Council. The information services provided by the Association employ a variety of means of communicating results of research to members, and the success which attended the publication of the B.I.S.R.A. Survey in 1952 has prompted the issue of a further survey on similar lines which is in the press at the moment. These publications stress the benefits to be had by applying the work done by the Association in co-operation with its members, and it is the response by members which accelerates the application of new ideas into industry. An example of how that leads to commercial developments is the recently formed group of member companies interested in the continuous casting of special steels. They have combined to finance and operate an experimental plant based on operating principles evolved in the Association's laboratories. It is hoped that this will be the forerunner of other collective projects to be financed and developed on similar lines. One such project under consideration at the moment is the development of the gas turbine for blast furnace blowing, whereby it is believed that substantial economies could be effected if sufficient support were forthcoming from member firms to warrant the building of an experimental unit as a prototype for the future."

Conference Studies New Flow Meter

Main sessions at a Sales Conference held by George Kent, Ltd., at Luton, on June 29th, were devoted to a detailed technical and commercial study of the new "KU" flow meter. Kent sales representatives, overseas branch company executives, and agents received a point-by-point briefing on the outstanding technical advantages of this new instrument. Commander P. W. Kent, R.N. (Retd.), Chairman and Joint Managing Director of George Kent, Ltd., was in the chair at the conference, and the following countries were represented : Australia, South Africa, Malaya, France, Belgium, Holland, Ireland, Sweden and Austria, as well as all areas of the United Kingdom.

The "KU" meter was on public view for the first time at the Second British Instrument Industries Exhibition at Olympia, from June 30th to July 11th.

Lubrication in Metal Working

By A. L. H. Perry, B.Sc. Tech., F.I.M.
The Shell Petroleum Co., Ltd.

In this article the author discusses the types, nature and capacities of the main lubricants used in metal working, whether in chipless forming or in cutting operations. Following an outline of the application of these lubricants in different metal working operations and on various metals, brief reference is made to the testing and evaluation of lubricants.

THE primary function of a lubricant is, of course, that of lubrication, for which purpose it should have anti-friction and anti-welding properties. In most cases, also, the lubricant is required to be a coolant, and for this purpose it should have good thermal properties (high specific heat, conductivity and latent heat), low viscosity, and good wetting power. The lubricant should also be non-corrosive and non-staining, both during the working process and in subsequent annealing; it should not be toxic or cause dermatitis; it should not have an unpleasant smell or fume badly. Of course, these desirable ancillary features cannot always be achieved to the required degree along with the primary function of lubrication.

The better the lubricant in terms of anti-friction, the lower the amount of heat liberated and the less that has to be dissipated. On the other hand, the best lubricant may not be the best coolant. The choice between these conflicting claims often depends on the particular operation. The highest cooling power is given by aqueous lubricants, and even when these are less efficient as lubricants than oils are, and thus permit more frictional heat to develop, they keep the work cooler.

Lubrication

There are of course two main types of lubrication—hydrodynamic or fluid lubrication, and boundary lubrication. In fluid lubrication, the rubbing surfaces are separated by a relatively thick film of lubricant. The fluid carries the load by the wedge action first explained by Osborne Reynolds; and the greater the viscosity of the lubricant, and the higher the relative velocity of the rubbing surfaces, the greater is its load-carrying power. Fluid lubrication is characteristic of components like plain bearings, but is, of course, never found in its full form in metal working. Here, boundary lubrication is the characteristic type. This is the condition in which rubbing surfaces are separated by a film of lubricant only a few molecules thick. In boundary lubrication, the coefficient of friction is much higher than in fluid lubrication—about 0·05–0·15 as against 0·001–0·003—and a characteristic feature is that it is always accompanied by wear—again unlike fluid lubrication, in which wear is negligible. Wear is the most important single aspect of the performance of metal working lubricants, and it is on their ability to minimise wear of dies, rolls and tools generally that they are most commonly assessed.

The coefficient of friction of mineral oils, under boundary conditions, can be reduced by the incorporation of certain additives, such as fatty acids, having polar molecules. This property of giving a low coefficient of friction is known as oiliness, and, in this sense, mineral oils have low oiliness. As is well known, the action of the polar additives depends upon the formation of an extremely thin adsorbed layer, but the original conception of the effect as one of pure physical adsorption has in recent years been modified, and it is now generally accepted than an essential feature is that the polar molecule should attack the metal, forming, in the case of the fatty acids, for example, metallic soaps. Where no such attack takes place, polar substances are very little, if any, better as boundary lubricants than non-polar substances.

Another factor of importance is chain length; other things being equal, the longer this is the better the substance is as a boundary lubricant. Thus solid hydrocarbons are better boundary lubricants than liquid hydrocarbons of similar type. If lubrication conditions are such that a solid boundary lubricant melts, then there is a corresponding drop in its effectiveness. Therefore, the higher the melting point the better. Incidentally, this largely explains why metallic soaps with typical melting points around 120° C. are superior to solid hydrocarbons, which normally melt at about 60°–90° C.

In many practical examples of boundary lubrication, conditions are mild enough to make a metallic soap, used as such or produced *in situ* by reaction of a fatty acid with one of the two metal surfaces, a very satisfactory boundary lubricant. In other cases, however, conditions are so severe that temperatures far in excess of the melting points of soaps are reached. This is the branch of boundary lubrication now known as Extreme Pressure Lubrication. A better term, some think, would be Extreme Temperature Lubrication, since the controlling factor in lubricant performance is the high temperature developed. The effective method of meeting these severe conditions is to produce an easily sheared and relatively infusible solid film between the working surfaces. The films generally produced are either sulphides or chlorides, or mixtures of these, and they are more effective than soaps, essentially because of their higher melting points. A typical E.P. lubricant consists of a mineral oil containing either a sulphurised or a chlorinated additive, or both together.

Sulphur may be added to the oil as elemental sulphur, or in a combined form such as a sulphurised fat. (Typical sulphurised fats contain 8–16% sulphur.) In either case, the sulphur reacts with the metal, at spots where the friction produces local high temperatures, to form a layer of sulphide which prevents the local welding that would otherwise occur. The sulphide most commonly encountered in practice is iron sulphide, and as this has a melting point of about 1,000° C., the advantages of sulphurised additives over fatty acids are

evident. Bowden has shown that such a film may be effective as a lubricant up to about 800° C.

Chlorine must of course always be added in the combined form—usually as a chlorinated hydrocarbon, such as a chlorinated wax. Typical waxes of this kind contain 40% chlorine. Like the sulphurised additives, they react locally at high-temperature spots to form anti-welding layers ; the layers largely consist of ferrous chloride, but ferric chloride and oxychloride are also present. Ferrous chloride melts at 600° C. and ferric chloride at 300° C., and Bowden has shown that such films are effective up to about 350/400° C. From the temperature aspect, therefore, chlorine is less effective than sulphur, but, on the other hand, chlorides as a class have lower shear strengths than sulphides and so tend to give lower coefficients of friction. Again, the chlorides begin to react at lower temperatures than the sulphides, and this is sometimes an advantage. Each type therefore has its value, and combinations of the two can produce useful lubricants with good performance under widely varying conditions.

While oiliness additives reduce the coefficient of friction, and thereby tend to reduce the rate of wear, E.P. additives may not decrease wear. In fact, E.P. additives sometimes increase the rate of wear as a result of their chemical attack on the rubbing metals ; their essential merit is their ability to prevent seizure by welding and thereby to prolong tool life. The oiliness additive is, therefore, typically anti-frictional, and the E.P. additive anti-welding, though of course most lubricants possess both qualities in some degree.

The general picture outlined above is shown in Table I.

Metal Working Oils

The main types of lubricant used in metal working are : mineral oils ; fatty oils ; compounded oils ; extreme pressure (E.P.) oils ; soluble oils (emulsions) ; drawing compounds (emulsions) ; soaps ; and graphite. There are of course many minor lubricants, such as soft metal coatings, that are applied in special cases. Let us now consider the nature and capacities of the main types.

Mineral Oils

These are essentially complex mixtures of hydrocarbons of various types—paraffins, naphthenes and aromatics—in proportions depending on the crude oil and the method of refining. The mineral oils used in metal working range from kerosene to heavy oils of the steam cylinder type—a very wide range considered in terms of viscosity. Mineral oils have excellent stability to oxidation and the lighter oils are good coolants, but they have very little oiliness and little anti-welding power and are, therefore, unable to cope with anything but mild conditions of boundary lubrication. However, such cases are common in metal working and straight mineral oils are therefore quite extensively used.

TABLE I.—TYPES OF LUBRICATING FILM

	TYPE OF FILM			
	Solid Organic	Soap	Iron Chloride	Iron Sulphide
Melting Point, ° C.	<100	about 120	about 600	about 1000
Example of Lubricant	Paraffin Wax, Higher Alcohols	Soap, Compounded Oils, Fatty Oil	Chlorinated Oil, Carbon Tetrachloride	Sulphurised Oil

Fatty Oils

Fatty oils such as rape oils and lard oils are much better boundary lubricants than mineral oils, because the glyceryl esters of which they are composed always decompose to give traces of free fatty acids, which give rise to improved oiliness. This makes fatty oils excellent metal working lubricants, but they have the serious defect of being very susceptible to oxidation, as a result of which they rapidly thicken and develop sludge. They are also now both expensive and hard to obtain, and are, therefore, rarely used.

Compounded Oils

These are blends of mineral oils and fatty material. A blend of from 10 to 30% of a fatty oil, such as rape oil or lard oil, in a mineral oil has lubricating properties roughly equivalent to those of the neat fatty oil—due, of course, to the fatty acids liberated from the fatty oil. Sometimes fatty acids themselves, e.g., oleic acid, are added, and the proportion is then usually only from about 1 to 5%, depending on the application. By varying the viscosity of the mineral oil, compounded oils can be produced to any desired viscosity, and with their excellent oiliness they constitute a type of oil of very wide usefulness, particularly in chipless forming. They are, in fact, used to a greater extent than any other type of metal working lubricant except the emulsions.

An important defect of compounded oils is that fatty materials are bad pro-stainers in the annealing furnace and this factor affects the selection of these oils for particular applications.

Fatty and compounded oils are excellent boundary lubricants but have little anti-welding power.

Extreme Pressure Oils

Extreme pressure oils are blends of mineral oils and E.P. agents. In the case of sulphurised E.P. oils, the sulphur may be added as elemental sulphur or as a sulphurised additive, such as a sulphurised fat. Elemental sulphur is dissolved by mineral oils to an appreciable degree—a naphthenic oil will take up about 0·7%—and still more sulphur is taken up, in a loosely combined form, if the oil and sulphur are heated at an elevated temperature. Oils of this kind have considerable E.P. properties but little oiliness. By adding the sulphur as a sulphurised fatty oil, however, both E.P. and oiliness properties are conferred. To get the maximum E.P. effect, both free sulphur and combined sulphur are necessary. E.P. oils containing free sulphur cause staining of yellow metal and, are, therefore, chiefly used on steel ; it is here of course that their powerful properties are particularly required. The sulphurised additives as a rule have very high viscosities, and this gives rise to blending problems in producing cutting oils of varying viscosities. The proportion of sulphurised additive in E.P. oils varies widely according to the application, the range being about 1–15%. Mineral oils themselves always contain appreciable quantities of sulphur derived from the original crude, but this is so strongly combined as to be ineffective as an E.P. agent.

Chlorinated E.P. oils consist of blends of mineral oil and a chlorinated additive, usually a chlorinated hydrocarbon. They are comparatively uncommon, but sulpho-chlorinated oils are widely used, and these, and sulphurised oils themselves, constitute the large majority of E.P. oils now in use.

As a class, E.P. oils are excellent boundary lubricants with powerful anti-welding properties.

Soluble Oils

Soluble oils consist essentially of mineral oil plus an emulsifying agent, and are used as dispersions in water. The term soluble oils is really a misnomer, since it implies the formation of true solutions instead of the colloidal dispersions actually formed. The emulsifying agents generally used in modern soluble oils are sodium or potassium soaps of the following: fatty acids, rosin, tall oil and naphthasulphonic acids. These soaps may be used individually or in combination, and in fact it is usually necessary to use more than one in order to get a well-balanced oil with an excellent level of performance in various directions, such as lubrication, stability and anti-corrosion. Other substances such as anti-foam agents and coupling agents may also be present.

The most common type of soluble oil gives opaque milky emulsions, but by increasing the proportion of emulsifier the clear type of oil, which gives translucent emulsions, is obtained. This sometimes gives better performance, for example in grinding, where wheel loading is retarded. These two classes of soluble oil have little oiliness or anti-welding power, but their combination of a small degree of lubricating power with high cooling power gives them wide applicability in metal working. Finally there are the E.P. soluble oils, consisting of an E.P. oil plus an emulsifying agent, which have a considerable measure of both oiliness and anti-welding power. These are, as yet, comparative novelties, but it is already clear that they show considerable promise and are likely to be extensively used in due course.

Drawing Compounds

These are emulsifiable pastes, usually of a creamy yellow colour. Basically they consist of mixtures of fat, soap, fatty acid and water, but mineral oil and special emulsifiers may also be present. They form opaque emulsions whose oiliness is much superior to that of the soluble oil emulsions, because of the fatty acids and soaps present. Drawing compounds for severe work often have additions of up to 50% of fillers such as talc, mica, chalk and zinc oxide. These serve as solid barriers between the rubbing surfaces and give the compound a considerable degree of anti-welding power.

Soaps

Dry powdered sodium and calcium soaps are used in steel wire drawing. Soap solutions are also used in various applications, either circulated, as in fine wire drawing, or applied by pre-dipping and drying, as in tube drawing. Soaps can also be dissolved in mineral oils, typical examples being aluminium stearate and lead naphthenate. Soaps have high oiliness but little anti-welding power.

Graphite

Graphite is very resistant to high temperatures and has a low shear strength, and, in consequence, is an excellent boundary lubricant. But its insolubility, which causes difficulties in its application and removal, and its colour, which is troublesome in relation to finish, limit its applications considerably.

Application of Lubricants

Let us now consider the application of these lubricants to the various metal working processes. These are divisible into two main groups—the chipless forming processes such as drawing and rolling, and the chip-forming processes, i.e., machining generally. Lubricant practice in these two groups differs considerably. Let us first consider chipless forming.

TABLE II.—MAIN LUBRICANTS USED IN METAL DRAWING

DRAWING PROCESSES	METAL		
	STEEL	COPPER & BRASS	ALUMINIUM
Tube & Bar	Drawing Compounds, Soaps, Fatty Oils	Drawing Compounds, Compounded Oils	Heavy Mineral or Compounded Oils
Press	Drawing Compounds, Compounded Oils	Drawing Compounds, Compounded Oils	Compounded Oils, Drawing Compounds
Wire	Soaps, Drawing Compounds	Drawing Compounds	Mineral and Compounded Oils

Chipless forming may be conveniently divided into hot working and cold working. Of these, hot working is much the less interesting from the lubrication aspect. Under hot working conditions, most metals are covered with a layer of scale which itself acts as a lubricant of sorts, and often makes the use of other lubricants unnecessary or ineffective. When other lubricants are used, their functions are to reduce die or roll wear, to prevent sticking, and to assist metal flow. The most versatile and generally useful lubricant for hot working is graphite, which is usually in the colloidal form in some convenient carrier—in water, as in Aquadag, in oil, as in Oildag, in blends of Oildag and oil, or in graphited greases. Graphite is effective as a lubricant up to temperatures of over 600° C. and, therefore, has a big advantage over most other lubricants. The oily carrier normally burns away leaving a graphite film on the rubbing surfaces. Graphited lubricants of one sort or another are common in forging and extrusion, but not in hot rolling. Here, the usual practice is to use no lubricant and merely to cool the rolls with water. The outstanding exception to this statement is aluminium and this is because aluminium forms no scale. Without a lubricant, therefore, pick-up of aluminium on the rolls would be excessive. The lubricant used is a soluble oil emulsion, at the appropriate strength to prevent excessive pick-up on the one hand, and slipping on the other. A concentration of about 2% of an opaque soluble oil is usually found suitable.

Drawing

We now turn to the cold working processes—drawing and rolling. Drawing comprises tube drawing, bar drawing, press drawing, and wire drawing. The main lubricants used in these processes are summarised in Table II.

Tube drawing and bar drawing are severe processes—particularly tube drawing. The lubricants may be applied by swabbing, by pre-dipping followed by evaporation, or by circulation. Fatty oils, drawing compounds (either neat or emulsified), soaps and compounded oils are the most common lubricants used for steel and copper. The aqueous type of lubricant is usually avoided for aluminium because of staining troubles, and heavy compounded oils or heavy mineral oils are preferred; the larger the tube and the heavier the draw, the heavier is the oil required. For presswork the most common type of lubricant is the drawing compound, used either neat for heavy work or diluted for lighter jobs. The heaviest types of operation may necessitate the use of filled lubricants or heavy compounded oils; and very light work may be done with

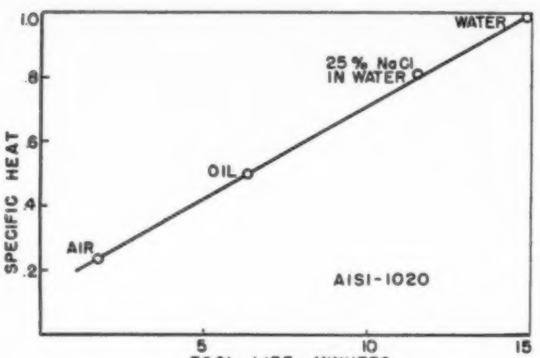


Fig. 1.—Effect of cooling on heat-limited tool life in lathe turning. (High speed steel tool cutting at 175 surface ft./min. ; depth 0·150 in. ; feed 0·035 in.)

soluble oil emulsions. Oils are often preferred to emulsions for aluminium because of the danger of water stains, and the heavier the job the heavier the oil that must be used.

In wire drawing, practice between the three metals varies considerably. For heavy steel wire, dry soap is almost universal, because of its ability to permit heavy reductions with low die wear. These properties give it a dominant position, in spite of its lack of cooling power, of its being a bad pro-stainer in annealing, and of its giving a bad surface finish. It has long been suggested that quasi-hydrodynamic conditions may be present in soap drawing, and quite recently Professor Thompson has given reasons for thinking that this may be true even at very low speeds. With fine wire, where unit die pressures are lower, drawing compound emulsions, and sometimes oils, are used. Turning to copper, die pressures here are not high enough to make dry soap necessary, and the standard lubricant is the drawing compound, the emulsion strength being lowered as the diameter falls. Exceptions to this generalisation are the use of fatty oils, such as tallow, at the inlet dies of rod machines, where die wear is otherwise very heavy ; of baths of pure rape oil, where this is plentiful and speeds are not unduly high ; of light compounded oils for drawing fine wire in alloys such as phosphor bronze ; and of soluble oil emulsions or soap solutions for very fine wire. Aluminium again presents special features. Emulsions are inadequate for anything but fine wire because of pick-up and breakage, and the standard lubricants are mineral or compounded oils, heavy oils being used for rod, and light oils for fine wire. The range of viscosities needed is very wide—for rod, viscosities of the order of 2,000 seconds Saybolt at 100° F. are required, whereas for fine wire the viscosity may be as low as 40 seconds. This need to increase the viscosity to match the severity of the job, a feature which is particularly noticeable with aluminium in general, is interesting as suggesting that some degree of hydrodynamic lubrication may be involved. The failure of emulsions to cope with heavy aluminium wire, whereas they are adequate for the stronger metal, copper is of course connected with the poor wettability and the high hardness of oxide of aluminium. This has a hardness of 9 on Moh's scale, as against 2 for aluminium itself. Such a difference is unusual, and Bowden compares it to a layer of ice on mud. The slightest load deforms the soft underlying metal, and break-through of the surface occurs. Where oxide and metal have similar hardnesses, as in copper, they deform together.

Rolling

Rolling is a particularly interesting process from the lubrication standpoint, because of the subtlety of the effects produced. The frictional conditions are a mixture of rolling and sliding, and as such are less onerous than in drawing. Rolling is unique in relying upon friction to carry the metal forward. Consequently, if friction is too low, rolling is impossible, and this imposes a lower limit on μ. But the lower the friction the higher the reduction for a given roll load, and from this point of view, and, of course, in relation to roll wear and heat generation, as low a coefficient of friction as possible is desirable. Rolling lubricants are usually either soluble oil emulsions or oils of low viscosity. These oils are usually lightly compounded, for example with rape oil or oleic acid, but straight mineral oils are sometimes used for cheapness. Emulsions are normally applied by circulation and perform the double task of cooling and lubricating. Oils are sometimes used in this same way, but sometimes they are applied in small amounts only, the cooling being done by water sprays on the rolls.

The main lubricants used in the cold rolling of metals are shown in Table III.

TABLE III.—MAIN TYPES OF ROLLING OIL

METAL		
STEEL	COPPER and BRASS	ALUMINIUM
Soluble Oils, Mineral Oils, Compounded Oils, Palm Oil	Compounded Oils	Compounded Oils

For cold rolling commercial and automotive body mild steel strip down to thicknesses of about $\frac{1}{32}$ in. the normal lubricant is a soluble oil emulsion. Special oils of low emulsifier content are generally used to give minimum staining on annealing, and the concentration is about 3–10%. For tougher steels, such as stainless steel or silicon steel, compounded or mineral oils of about 100 seconds Saybolt at 100° F. are often used as they permit higher reductions than the emulsions. Tinplate strip is a special problem because at these low thicknesses rolling pressures are particularly high. Long experience has shown that palm oil, applied neat or as an emulsion, is particularly effective in resisting these high pressures, and its use, or that of other similar fatty materials, is therefore nearly universal in this application. In re-rolling work, emulsions or light compounded oils are again general, the choice depending upon the steel, the mill, and the type of finish required. Finish is particularly susceptible to the lubricant in rolling operations. Too effective a lubricant may give a dull finish by preventing the rolls from burnishing the strip ; but too poor a lubricant may give a bad finish due to abrasion and pick-up. There is therefore a mean range which must be found to suit each particular job.

For rolling copper and brass, compounded oils are almost universal. For the breakdown passes it is common to use an oil based on a conventionally refined mineral oil, but for the finishing passes prior to annealing, a light compounded oil based on a highly refined mineral oil is usual, to give minimum staining on annealing.

Emulsions are avoided with aluminium because of water staining, and compounded oils are universal. The avoidance of staining on annealing is particularly difficult with aluminium, because of the low annealing temperatures, and light, highly refined mineral oils with carefully chosen compounding additives must therefore be used. Oils of this type, with viscosities of only about 45 seconds Saybolt Universal at 100° F., circulated in very large volumes, are used in the modern multi-stand high-speed mills producing aluminium strip and foil.

It will have been noted that in this survey of the lubricants used in chipless forming, no mention has been made of E.P. lubricants. This omission is deliberate: E.P. agents are occasionally used in this field, but only in marginal cases and usually with only marginal effects. For example, in some field trials on copper wire drawing, the addition of a powerful chlorinated additive to a drawing compound had no appreciable effect in improving die life, though this particular additive would be extremely effective in machining copper. In fact, in the field of machining, E.P. agents have very profound effects, as will be seen.

Cutting Oils

Water, soap solutions, mineral oils, fatty oils, compounded oils—these were the cutting fluids available until about a quarter of a century ago. Mineral oils and compounded oils are still quite extensively used, and fatty oils occasionally so, but the field of cutting is now largely dominated by the soluble oil and the E.P. cutting oil, in their various types.

In any machining process, the virgin surface of the underside of the chip presses heavily against the face of the tool, which likewise is a clean uncontaminated surface from the rubbing action. Ideal conditions for easy welding therefore exist, much more so than in chipless forming. Equally, the operative surfaces are more readily attacked by any E.P. agent present in the lubricant. On the other hand, the quasi-hydrodynamic conditions sometimes observed in chipless forming do not appear to exist in machining.

Under very mild conditions, no cutting oil at all may be needed; in the next stage come emulsions and mineral oils; then fatty oils and compounded oils; and finally the E.P. oils, which can be and are made in various degrees of strength to match various conditions of severity. Factors that play a considerable part are the cooling power of the lubricant and the ease with which it can get to the point of application, in both of which viscosity is involved. The various factors are interdependent and differ in relative importance in various cutting operations. Under controlled experimental conditions, however, these functions can be sorted out to some extent and related to practice. Recent work has shown that there appear to be three essential types of tool failure, depending on whether the failure is caused by heat, wear, or welding.

Where tool failure is due to excessive heat, the best tool life will obviously be given by the fluid with the best cooling power. Fig. 1 shows the effect of various fluids under conditions of this kind, as determined in some tests on lathe turning. Cooling is seen to be the dominating feature, and alterations in viscosity or the coefficient of friction had no effect.

This cause of failure—excessive heat—applies in the case of severe drilling, but, paradoxically, coolants are not effective; this is because they cannot, under ordinary conditions, reach the tool point in sufficient volume, but if a hollow drill is used, so that the fluid can really get to the drill point in effective quantity, enormous increases in drill life can be obtained. This is illustrated in Fig. 2.

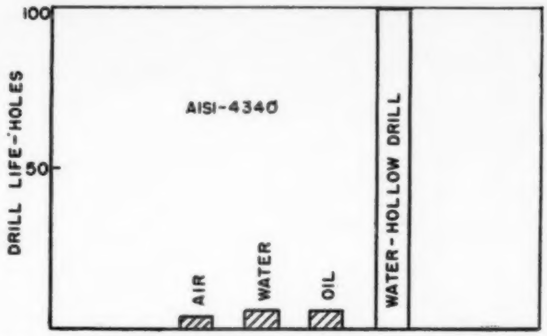


Fig. 2.—Effect of cooling on drill life ($\frac{3}{8}$ in. drill cutting at 1,240 r.p.m.; depth 1 in.; feed 0·006 in./rev.).

Under these same conditions of tool failure due to excessive heat, E.P. agents will give a small increase in tool life. How they do this was elucidated in some experimental lathe turning, in which the forces at work were measured by dynamometers and could be analysed into surface friction and shearing forces. The E.P. oil gave an overall reduction in friction, as shown in Fig. 3. and analysis showed that this was due, not to a reduction in surface friction (Fig. 4), but to a reduction in the shearing forces (Fig. 5).

In the second type of failure, due to excessive wear, friction is the dominant factor and cooling is relatively unimportant. Oil is then considerably better than water, as shown in Fig. 6. Under these conditions E.P. agents may increase wear. The viscosity of the oil is important whether it is a straight oil or a dispersion in water (Figs. 7 and 8). There appears to be an advantage in increasing viscosity from kerosene to light oil, particularly at high speed, but mechanical factors later intervene and limit the improvement, and a heavy oil is less satisfactory.

In the third type of failure, where life is limited by welding, the effect of E.P. agents is predominant. Tool life may be increased from ten to twenty times by their use. Cooling with water is less effective, and oil alone has no significant effect. As in the second type of failure, the E.P. agent may actually increase the wear, but it so increases the ability to withstand high loads without failure from seizure, that tool life is greatly prolonged. The overall effects of E.P. agents on the three kinds of tool life are shown in Fig. 9.

How the interplay of factors such as the above may alter the relative merits of various cutting oils in different operations is illustrated by the figures obtained in production reaming and tapping of certain mild steel components (Table IV).

Evaluation of Metal Working Lubricants

The large scale and high speed of modern processes makes it very desirable to find small scale rigs that will give accurate indications of performance. This is usually rather difficult, both from the angle of reproducibility of results, and that of successfully relating the results obtained to shop conditions.

In chipless forming, the main criterion of performance is wear, and as this is so slight with modern die materials

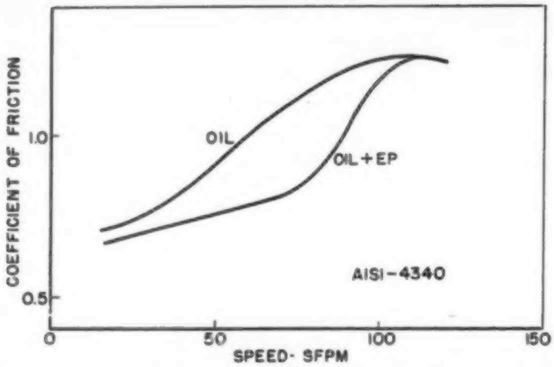


Fig. 3.—Effect of extreme pressure agents on the coefficient of friction between chip and tool in lathe turning. (High speed steel tool ; depth 0·150 in. ; feed 0·0057 in./rev.).

most workers on the subject measure friction and assume that this is proportional to wear, which is not always true. With this in mind, some attempts were made to measure wear itself in wire drawing. Copper wire was drawn vertically by simple direct loading with weights through a radioactive tungsten carbide die. The pick-up of tungsten on the wire was readily detectable, but it was of an erratic nature and the method could not be used successfully for evaluating lubricants. Somewhat unexpectedly, the best indication we have so far found of the merits of copper wire drawing lubricants is to test their frictional properties in a Bowden friction apparatus, in which a plate of copper is moved slowly under a loaded tungsten carbide slider. This is understandable on the view that, whatever the exact condition of lubrication in wire drawing, the wear is due to boundary friction, which is what the Bowden machine measures. Of course, the usefulness of any such method must depend on being able to set some scale of reference by measuring the laboratory performance of some lubricants of known field performance ; ultimately field trials are unavoidable, as it is not practicable for oil companies to instal their own metal working equipment. A compromise arrangement which we have sometimes used is to hire a draw bench, say a tube-drawing bench, instrument it, and carry out trials under our own supervision.

TABLE IV.—REAMING AND TAPPING OF MILD STEEL COMPONENTS PERFORMANCE OF VARIOUS CUTTING OILS

CUTTING OIL	TOOL LIFE—COMPONENTS PER TOOL	
	REAMING	TAPPING
E.P. Soluble Oil (15% Emulsion)	3,100	1,600
Powerful Sulphurised E.P. Cutting Oil	1,800	21,000
Opaque Soluble Oil (15% Emulsion)	700	NOT TESTED

The tubes, etc., of such trials can then be marketed in the usual way. Even this method breaks down, however, in the case of the largest type of unit, such as say a multi-stand rolling mill. It is just not possible to experiment, in the ordinary sense, on such a unit, but neither can it be assumed that the results of laboratory or small scale rolling tests will necessarily be a true guide to performance in the big mill. In such cases, one can only go so far and then try to persuade the manufacturer to make a trial, which he is often reluctant to do because of the expense and interruption of production. In these circumstances, progress in developing lubricants is sometimes rather slow.

Evaluation in the field of machining is not quite so difficult. Machine tools of sorts are always available, and it is also practicable to instal special machine tools for experimental purposes. Even so, to conduct tests on such machines is expensive in time and in metal, and it is therefore often helpful to use special test rigs such as those used for evaluating E.P. properties. Two of the best known are the 4-ball machine and the Timken machine.

The 4-ball machine makes use of standard hardened-steel bearing balls. A ½ in. diameter ball of this type is held in a chuck and revolves at constant speed under load in contact with three identical stationary balls which are locked together in a cup containing the oil to be tested. Loading can be varied as desired, and out of several tests the most usual is to do a series of 1 minute runs under various loads. Friction is recorded continuously and automatically throughout each run, and the wear scars on the balls are measured at the end of each run, so that a wear/load relationship is established. This and the friction give useful information on the activity of the

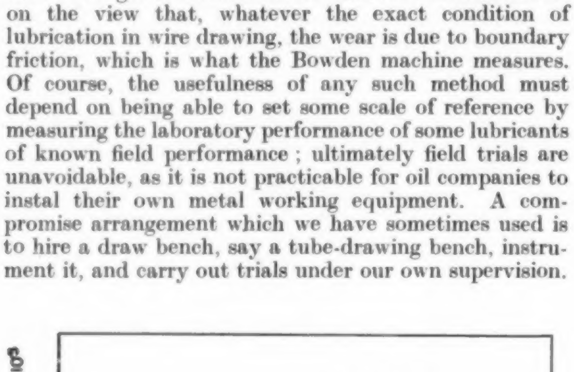


Fig. 4.—Effect of extreme pressure agents on friction at tool surface in lathe turning. (High speed steel tool ; depth 0·150 in. ; feed 0·0057 in./rev.).

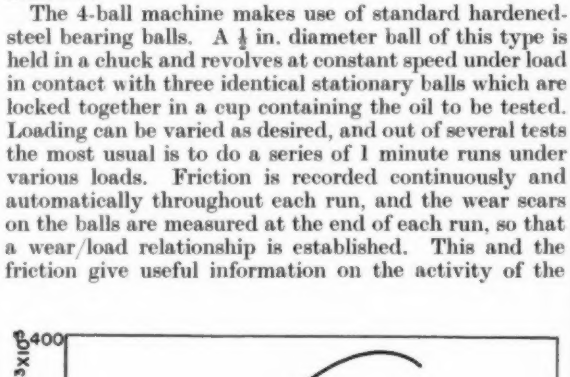


Fig. 5.—Effect of extreme pressure agents on shear work on chip in lathe turning. (High speed steel tool ; depth 0·150 in. ; feed 0·0057 in./rev.).

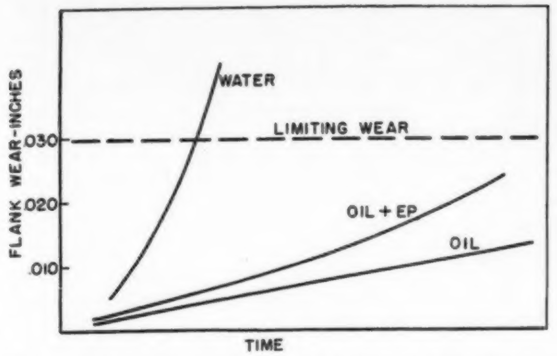


Fig. 6.—Effect of lubrication on tool wear in lathe turning. (High speed steel tool cutting at 130 surface ft./min.; depth 0·075 in.; feed 0·020 in./rev.; A.I.S.I. 1020 steel).

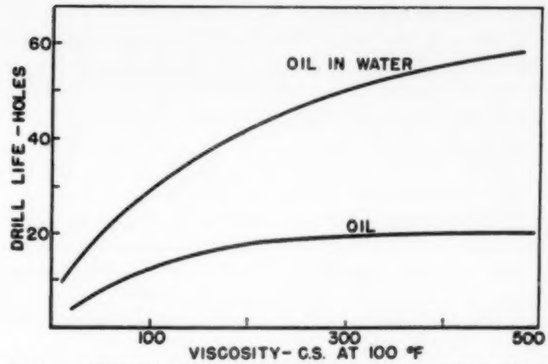


Fig. 7.—Effect of viscosity on drill life. ($\frac{3}{8}$ in. drill cutting at 1,240 r.p.m.; depth 1 in.; feed 0·006 in./rev.; A.I.S.I. 4340 steel).

E.P. agent. Another method of test is to find the load that will just lead to seizure in 2½ seconds.

In the Timken machine a steel ring is rotated at constant speed under load against a steel block, the whole being flooded with the lubricant under test. The usual method of test is to run a series of 10-minute runs with increasing loads until the load is reached at which the scar on the block shows a sharp transition from a smooth to a scored finish. The load-carrying capacity of the oil is taken as this load less 1 lb., and is known as the Timken O.K. value.

Though these tests are very useful, it is found that they cannot be closely related to the performance of E.P. cutting oils in practice, and they are, therefore, chiefly used as guides to the potentialities of new E.P. additives and checks on the consistency of performance of new batches of additive. Another method of evaluating E.P. activity is by the sulphur release test, which measures how much sulphur is liberated as free, or active, sulphur at elevated temperatures. The oil is heated at selected temperatures—usually 100° C. and 200° C.—in contact with copper turnings or bronze powder, with which the released sulphur combines. This is then estimated chemically by the usual analytical methods. An entirely similar test, the chlorine release test, is used for chlorine.

The object of performing the test at two temperatures is to see how the rate of release varies, because this is important in relation to service performance. In general it is desirable that the amount released at 100° C. should be low, but the amount released at 200° C. should be high. Oils that meet these provisions will not readily stain yellow metals but will be suitably active at the points of contact where high temperatures are generated. A standard form of this test will shortly be issued by the Institute of Petroleum.

As these and other small scale tests do not correlate closely with field performance, actual machining tests are essential when really accurate assessments of cutting oils are wanted. Drilling, tapping and turning tests are used in this way. Great care in the selection of the tools and the metal drilled is necessary if even reasonably repeatable results are to be obtained. Similarly, actual machining operations in the field, if properly controlled, may be used to assess oils. For example, collaboration over a period of years with a manufacturer using rigidly controlled reaming and tapping operations in a standard component has produced results of mutual interest and value that could hardly have been obtained otherwise.

Impact of Technical Progress

Looking back over what has been said, we see that the fundamental lubricants in chipless forming are soaps, emulsions and compounded oils, and in machining, emulsions and E.P. oils. With this in mind it is of interest to consider what advantages to the art and practice of metal working have resulted from the general developments in luboil technology over the last 25 years.

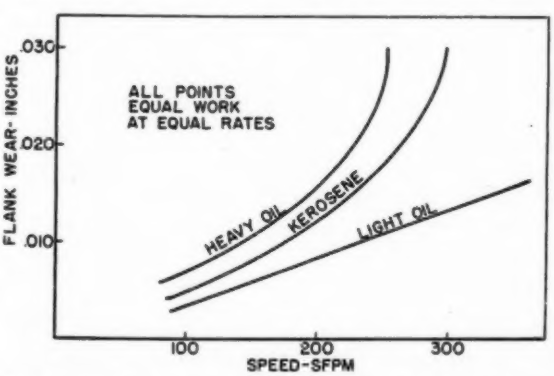


Fig. 8.—Effect of viscosity on tool wear in lathe turning. (High speed steel tool; 20 cu. in. of metal cut at 2·35 cu. in./min.; depth 0·075 in.; A.I.S.I. 1020 steel).

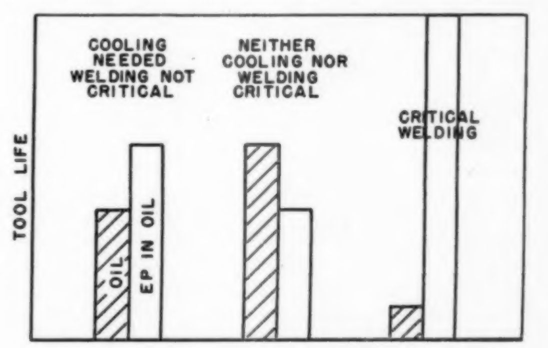


Fig. 9.—Typical effects of extreme pressure agents on tool life limited by cooling, wear and welding (various operations).

These may be summarised as follows :

(1) The new methods of solvent refining have provided lubricants, notably rolling oils, with reduced tendency to cause staining in annealing. This benefit is confined to chipless forming—the highly refined oil is commonly not needed in cutting oils.

(2) The soluble oil, which is about 25 years old, has proved an extremely flexible and attractive lubricant for all kinds of metal-working processes, hot and cold, chipless and chip producing. Modern emulsifiers, notably the naphthasulphonates produced as by-products in petroleum refining, have helped to improve the stability of the emulsions. Steady development in soluble oils is still taking place, notably in the E.P. soluble oil and the soluble oil using non-ionic emulsifiers.

(3) The E.P. oil, which is now about 20 years old, has proved invaluable for meeting the severe demands of modern machining.

On the other hand, many of the advances in oil technology play no part in the field of metal working. Additives such as oxidation inhibitors, corrosion inhibitors, pour point depressants, detergents, etc., which have had such a profound effect on the performance of engine and machine lubricants, are almost unknown in the field of metal working where their particular advantages are not needed.

The Nickel Bulletin

SIMPLE tests to identify some nickel alloys and other metals, devised primarily for use in the shop or scrap yard, are described in the April Nickel Bulletin. Items of interest in the Abstract Section include a reference to an index of specifications which correlates schedules issued by U.S. Governmental and other standardising bodies. The procedure used by the Aluminium Company of America for nickel-plating aluminium-base materials is also described, with special reference to zincate pre-treatment.

Reference is made to several major publications on steels, including a comprehensive report on physical constants of steel at elevated temperatures, laboratory studies of thermal stabilization of iron-carbon-nickel alloys, the influence of hydrogen on the tensile properties of steels, and recommended methods for spectrographic analysis of low-alloy steels.

Abstracts relating to high-temperature materials include an account of thermal shock tests on austenitic and ferritic piping materials, a discussion of shielded arc welding processes for high-temperature materials used in jet engines, and a study of the behaviour of refractory oxides in contact with metals at high temperatures. The results of research on the resistance of cast iron-chromium-nickel alloys to corrosion by oxidising and reducing flue gases are also abstracted. Austenitic steel abstracts include a report on the occurrence of stress-corrosion cracking, and data on the effect of cold working on the magnetic properties of high-alloy chromium-nickel steels.

The Nickel Bulletin is published by The Mond Nickel Co., Ltd., Sunderland House, Curzon Street. London, W.1.

Elliott Newcastle Office

ELLIOTT BROS. (LONDON), LTD., manufacturers of electrical, electronic and process control instruments, announce the transfer of their Newcastle branch office as from June 1st, 1953, to larger and more modern premises at 36, Scottwood Road, Newcastle-on-Tyne (Telephone : Newcastle 23811). The move follows the company's increasing business activities and close co-operation with instrument users in Newcastle and adjoining counties. The new premises provide showroom facilities with a window facing the main thoroughfare, ample office accommodation and workshop space for the many activities of the Service Department.

This new branch office is now the area sales, service and instrument repair centre for Northumberland, Cumberland and Westmorland, Co. Durham and the Cleveland district of Yorkshire, including Middlesbrough. The company's process control interests are in the hands of Mr. E. F. Millican, while Mr. R. J. Rowe specialises in electrical measuring instruments.

Financing of the European Productivity Agency

FINANCIAL arrangements for the European Productivity Agency, set up by decision of the Council of the Organisation for European Economic Co-operation on May 1st, 1953, have been agreed upon by the Council. The United States Special Representative in Europe has informed the Secretary-General of the O.E.E.C. that his Government is prepared, subject to certain conditions, to transfer to the O.E.E.C. for the exclusive use of the Agency up to \$2,500,000. The new decision refers to the contribution of the Organisation to the running of the Agency and the special contributions to be made by certain Member countries.

The Budget of the Organisation for the financial year 1953/54 will contain an allocation of 150 million French francs to be made from the assets of the Organisation for the purposes of the Agency. As far as special contributions are concerned, Member countries which have concluded special agreements with the United States Government in compliance with the Economic Co-operation Act of 1948 and the Mutual Security Act of 1951, have undertaken to pay to the O.E.E.C. for the European Productivity Agency a portion of the counterpart funds deposited in accordance with these agreements. This amount will equal 8% of the counterpart funds, and will be paid by Member governments at the latest as soon as the counterpart funds are deposited.

These special contributions fall into two parts. First, not less than one-third of the contribution will be in transferable currency, available for expenditure in the monetary area of the European Payments Union. The remaining part will be expendable solely in the currency of the contributing country, unless that country agrees to permit its expenditure in the currency of another Member country. These amounts will be administered by the Secretary-General in accordance with general principles to be agreed between the Organisation and the contributing Member countries. Arrangements have also been approved for quarterly reports on the activities of the Agency and its finances, and for final financial obligations on termination of these activities.

Efficient Structures in Aluminium

By M. Bridgewater, B.Sc.
Development Engineer, Northern Aluminium Company, Ltd.

Economical design of aluminium structures cannot be achieved unless the properties of the metal are exploited and its limitations understood. In this article the author summarises the significant differences between aluminium and steel as structural media, and refers to the latest views on the design of light alloy members. Current riveting and welding practice are touched on and some recent aluminium structures reviewed.

STRENGTH, lightness and durability make aluminium an inherently excellent structural material. Although these characteristics have long been exploited by the aircraft constructor, there has, for various reasons which include the comparative scarcity and unfamiliarity of the metal, been little serious use in the building and structural fields until recent years. Since the War there has been a rapid awakening of interest; much more information on aluminium has become available to the engineer, and it is estimated that in the first six post-war years more than a quarter-million tons were used in the building and structural spheres. The properties of aluminium are very different from those of steel, and it is necessary in efficient design to treat aluminium on its own merits. This article presents a discussion of some of the problems that arise from this approach.

Choice of Alloy

As experience has been gained, considerable attention has been paid to the choice of the alloy most suitable for structural work, and there is now a fair unanimity in favour of the aluminium-magnesium-silicon type. Though not one of the strongest alloys, this material offers ample strength in view of the frequency with which other factors, such as stability, are found to determine design; also it is far superior to the high-strength alloys in corrosion-resistance, and is much more economic.

This alloy, which is the only one to be considered in this review, is available as extruded sections, plate, sheet, wire and forgings, and the mechanical properties are developed by working and heat-treatment. It is normally used in the "fully-heat-treated" state, though if much forming is necessary the more ductile "solution-treated only" material may be called for. Minimum properties for both these conditions, in the various forms, are laid down by British Standard Specifications. Although specification minima should be used in design, considerably higher figures are in practice realised by the material. This is shown by Table II, which also lists some of the other typical properties.

Characteristics. The stress/strain curves in Fig. 1 show a typical lack of sharply-defined yield, which has led to the adoption of an arbitrary "0·1% proof stress" corresponding to a permanent set of 0·1% on a standard 2 in. gauge-length. Young's modulus is $9{\cdot}5 \times 10^{6}$ lb./sq. in., or about one-third that of steel, and this has a profound effect on design in light alloy, not only because deflections are greater but because compression members become prone to elastic instability

TABLE I.—BRITISH STANDARD SPECIFICATIONS FOR MAGNESIUM-SILICON ALUMINIUM ALLOY

Manufactured Form	British Standard Specification	Chemical Composition	Guaranteed Minimum Mechanical Properties		
				W	WP
Extrusions	BS1476 HE10	Mg. 0·4–1·5% Si 0·75-1·3%	0·1% Proof Stress Ultimate Tensile Stress Elongation	7 tons/sq. in. 12 tons/sq. in. 18%	15 tons/sq. in. 18 tons/sq. in. 10%
Sheet	BS1470 HS10	Mg. 0·4–1·5% Si. 0·75–1·3%	0·1% Proof Stress Ultimate Tensile Stress Elongation	7 tons/sq. in. 12 tons/sq. in. 18%	15 tons/sq. in. 18 tons/sq. in. 10%
Plate	BS1477 HP10	Mg. 0·4–1·5% Si. 0·75–1·3%	0·1% Proof Stress Ultimate Tensile Stress Elongation	7 tons/sq. in. 13 tons/sq. in. 12%	14 tons/sq. in. 18 tons/sq. in. 8%
Forgings	BS1472 HF10	Mg. 0·4–1·5% Si. 0·75–1·3%	0·1% Proof Stress Ultimate Tensile Stress Elongation	7 tons/sq. in. 12 tons/sq. in. 18%	15 tons/sq.in. 18 tons/sq. in. 10%

W indicates solution treated only.
WP indicates fully heat treated.

TABLE II.—TYPICAL PROPERTIES OF A MAGNESIUM-SILICON ALUMINIUM ALLOY CONFORMING TO HE10 of BS.1476

			W	WP
Composition	Si 1% Mg [illegible]% Al remainder	0·1% Proof Stress (tons/sq. in.)	9	18
		Ultimate Tensile Stress (tons/sq. in.)	15	20
Modulus of Elasticity	$9{\cdot}5 \times 10^{6}$ lb./sq. in.	Elongation %	20	13
Density	0·098 lb./cu. in.	Bearing Yield Stress (tons/sq. in.)	15	20
Thermal Expansion	24×10^{6}/°C. (20–200° C.)	Ultimate Shear Stress (tons/sq. in.)	10	14
Specific Resistance	W 3·9, WP 3·6 microhms/cm. cube	Fatigue Strength (for 50 million cycles; tons/sq. in.)	6	6¼
		Brinell Hardness	60	90
Thermal Conductivity	0·44 C.G.S. units at 100° C.	Izod Impact (ft. lb.)	30	7

W indicates solution treated only.
WP indicates fully heat treated.

The corrosion resistance of HE10 is high and painting is seldom required except in special circumstances, for instance where there is a risk of bimetallic reaction An important aspect of this durability is that very little section thickness need be added to allow for wastage, and thicknesses as low as 0·08 in. are suitable for stressed members.

Low density (0·098 lb./cu. in.) combines with the properties of this alloy to give a very good strength/weight ratio in comparison with structural steel. Owing to the low Young's modulus, however, full advantage cannot be taken of this; in practice, the light alloy

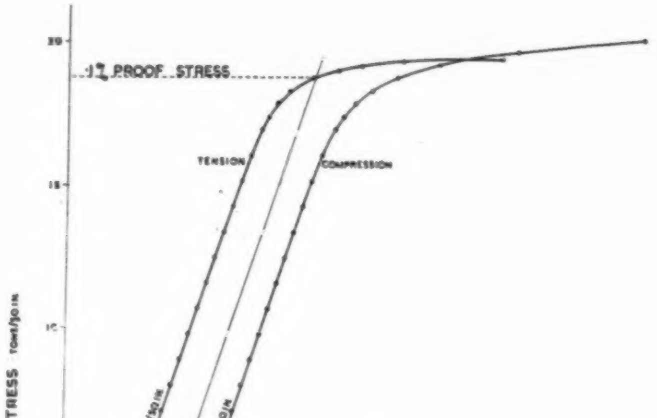


Fig. 1.—Typical stress-strain curves for HE 10 WP.

objectionably large, so it becomes more important to calculate deflections; the natural frequency of the structure must also be considered more often. The tendency is, therefore, to use deeper beams and more lattice frames than in steel practice.

At present, various codes and specifications stipulate maximum deflections, based on steel practice, that are an unnecessary handicap in light alloy design, and it is hoped that they will in time be revised.

Instability. Compression members under axial loading fail either by overall flexural buckling, by local buckling, or by torsional buckling. The type of failure depends on the geometry of the cross-section, the slenderness ratio and Young's modulus, and it is usually possible to consider the three types of failure separately, though in unsymmetrical sections failing load may sometimes be reduced by an interaction of torsion with overall flexure.

In steel columns of standard section, failure almost invariably occurs by overall flexure, and the designer is seldom concerned with the other modes of failure, but the lower stiffness of aluminium makes them of practical significance.

Overall Flexural Buckling. In struts of compact cross-section, Eulerian failure can be predicted by the Perry-Robertson formula, using the 0·1% proof stress as a yield stress; values of the Perry constant appropriate to various alloys are available. Fig. 3 shows a Perry-Robertson strut curve for HE10WP.

Torsional Buckling. In this form of failure, illustrated in Fig. 4, the axial load causes twisting of the centre of the column relative to the ends. Though virtually unknown in steel members, it can occur with many aluminium sections.

The compressive stress at which pure twisting of a section will occur is given by:

$$P_t = \frac{GJ}{I_p} + \frac{\pi^2 EW}{L^2 I_p}$$

where G = Shear modulus ($3\cdot8 \times 10^6$ lb./sq. in.).
J = Torsion constant.
W = Warping constant.
I_p = Polar moment of inertia about the centre of twist.

structure weighs 40–45% as much as its steel equivalent, though in exceptional cases this figure has been as low as 20%.

The typical elongation for HE10WP (13% on a 2 in. gauge-length) is more than enough to permit the necessary stress redistribution at joints.

From the S/N curve in Fig. 2, it will be seen that the fatigue strength of the alloy is $6\frac{1}{2}$ tons/sq. in. for 50 million cycles (there is no "fatigue limit" as for steel). This is so much more than adequate for most types of structure that, unless a large number of substantial variations of load is expected, fatigue need hardly be considered.

Design Problems

The comparatively low Young's modulus (E) of aluminium produces problems that do not present themselves to the designer in steel.

Deflections. The lower E permits deflections that, though associated with safe stresses, may sometimes be

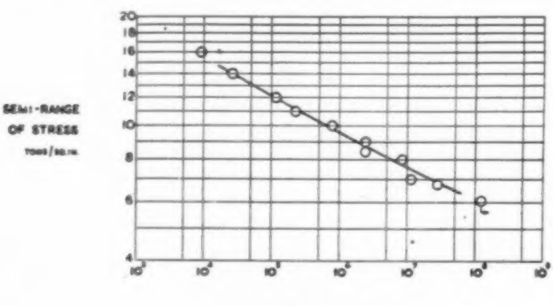


Fig. 2.—Fatigue curve for HE 10 WP.

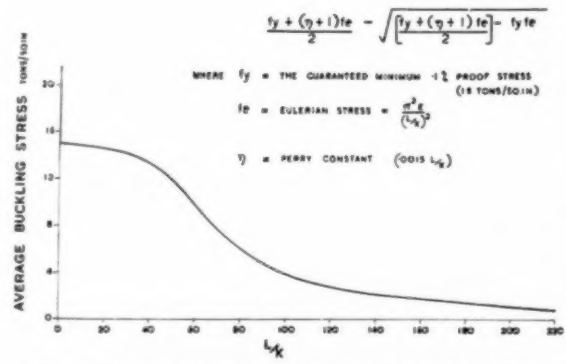


Fig. 3.—Perry-Robertson strut curve for HE 10 WP.

The second term, allowing for warping restraint, only becomes of importance in short struts. The torsional crippling stress is, therefore, largely dependent on the ratio of torsional stiffness to polar moment of inertia, and in thin open sections, where J becomes very small compared with I_p, it can fall below the flexural crippling stress. The calculation depends on an accurate value of the torsion constant. An amendment to BS.1161 gives torsion constants for standard aluminium sections, and for others the value can most conveniently be found by considering the component rectangles of the section and adding the effect of fillets and bulbs, which can be very considerable. Fig. 5 shows an example of the rapid increase of torsion constant with increasing fillet radius.

Though the flexural and torsional types of failure are independent of each other in sections having two planes of symmetry, most structural sections have only one. Interaction may then reduce the failing load, as illustrated in Fig. 6. The following is a general formula for failure of struts with one plane of symmetry :

$$(P-P_1)\,[r_o^2(P-P_2)\,(P-P_3)-x_o^2P^2] = 0$$

where P = Buckling stress.
P_1 = Eulerian stress in the plane of symmetry.
P_2 = Eulerian stress perpendicular to the plane of symmetry.
P_3 = Torsional failing stress.
r_o = Polar moment radius of gyration about the centre of twist.
x_o = Distance of centre of gravity from centre of twist.

Courtesy of Aluminium Laboratories Ltd.

Fig. 4.—Torsional failure of a channel.

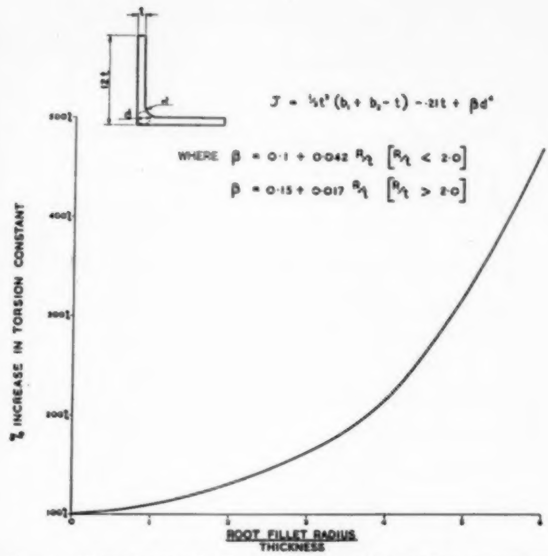


Fig. 5.—The effect of fillet radius on the torsion constant.

Deep channels are prone to serious interaction, shallow channels and equal angles much less so.

Local Buckling. Compressive buckling (Fig. 7) may occur locally at stresses well below those necessary to cause failure. The load at which this begins is dependent on the amount of restraint present, and can be expressed by :

$$f_c = 0\cdot923\ KE\left(\frac{b}{t}\right)^2$$

Where K is a constant depending on the degree of restraint. Values of K are shown in Fig. 8. Lips and fillets help to prevent local buckling.

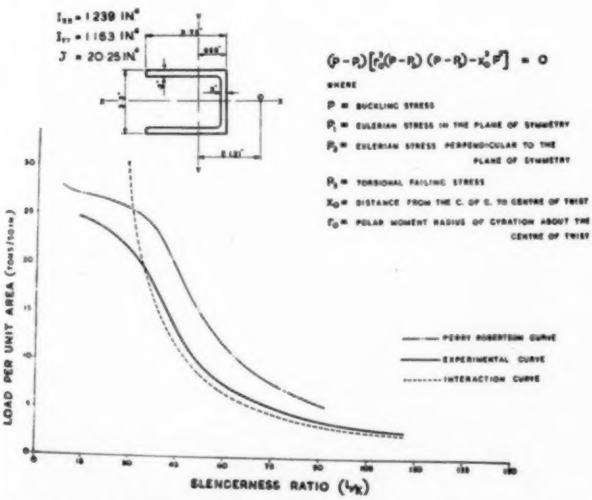
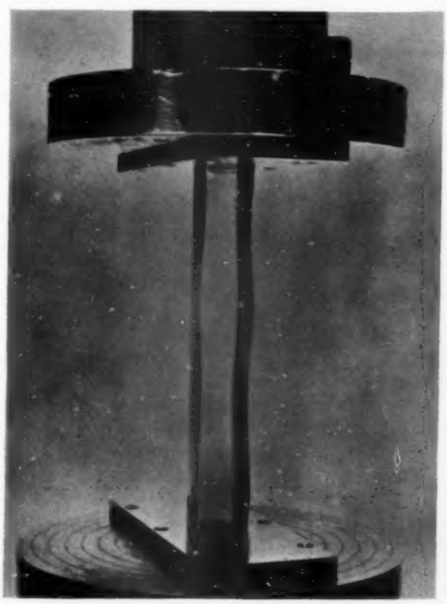


Fig. 6.—Interaction of flexure and torsion on a deep channel.

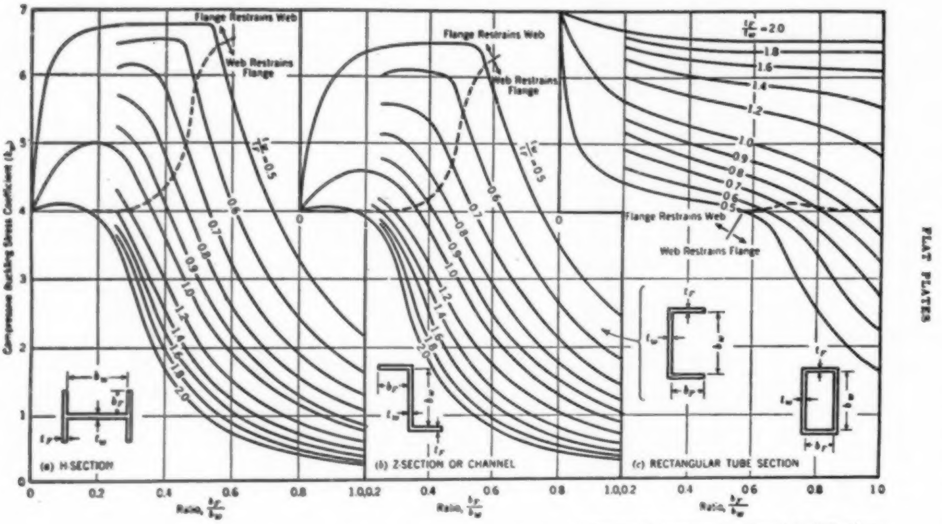


Courtesy of The Building Research Congress

Fig. 7.—Local failure of a channel.

Local buckling stress $p_c = .923\ k_w E \left(\frac{t}{b}\right)^2$

where k_w is obtained from the appropriate graph



Courtesy of American Society of Civil Engineers

Fig. 8.—Determination of local buckling stress.

Lateral Instability. This type of failure of slender unrestrained beams is accentuated by the use of aluminium. Empirical rules that have been proposed for its prevention would limit the ratio of unsupported span to flange width to 17 to 1 in the case of HE10WP, but under certain conditions, this recommendation will be very conservative. Other design rules that have been suggested take loading conditions and warping restraint into account and make more economical detailing possible.

The general theoretical solution for the lateral instability stress is given by :

$$f_c = \frac{C}{Z_2 L}\ \frac{EI_1 GJ}{\gamma}\ \left[1 + a\,\frac{\pi^2 W}{GJL^2}\right]^{\frac{1}{2}}$$

where a = end restraint constant.

$$\gamma = \frac{I_2 - I_1}{I_2}$$

W = Warping constant.

C = Load factor.

To avoid instability, sections with a high J, or nearly equal moments of inertia, should be used. This can be done by adding bulbs and fillets, or adopting double or hollow members. Small lateral restraints, as from other members resting across one flange, have been found to raise the critical load considerably. Fig. 9 shows the effect of restraint.

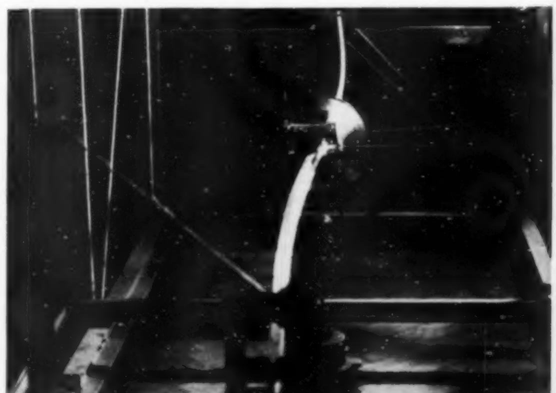
Economical Design

The cost of aluminium is high in relation to steel (about three times on a volume basis) and it must therefore be used efficiently if it is to compete. Greater care in design and elaboration of sections are justified, and have especially to be directed towards efficient compression members. Two characteristics of aluminium that assist the designer are the economy with which complex sections can be extruded and the small thicknesses of metal that can be used without risk of corrosion.

Prolonged design work is not always justified by the job in hand, however, and there is need of a range of standard sections designed to make really efficient use of the material (the designs in BS.1161 are based on steel sections and, though useful, are often uneconomic and prone to premature failure). Suitable sections have now been developed independently by many engineers, with remarkable unanimity as to form.

Design of Efficient Sections. High moments of inertia and section moduli are obtained by placing the metal as far as possible from the neutral axis. The result is a thin section which must be stabilised by large fillets, lips or bulbs. Practical considerations, such as joining, influence design, but satisfactory compromises have been attained. Optimum efficiency—simultaneous failure by flexure, torsion and local buckling—should be aimed at for the minimum slenderness ratio at which the strut will be used.

To be of real value, the critical stress for each form of instability should be included in the tabulated properties



Courtesy of The Building Research Congress

Fig. 9.—Lateral instability of a restrained I-beam.

of each section. Much of this information would have to be found by practical test, but the volume of testing could be minimised by adopting geometrically similar ranges of sections, all the properties being expressed as a function of the thickness.

$$I = k_1t^4 \qquad J = k_2t^4 \qquad Z = k_3t^3$$
$$A = k_4t^2 \qquad r = k_5t$$

where k is constant for sections in any geometrically similar range.

Crippling stresses for torsional or local failure could then be expressed as a non-dimensional ratio independent of section size, and only a limited number of sections would have to be tested. Further, designers could reproduce a section in sizes intermediate to the standard ones; properties would easily be determined, and the saving in metal would often amply justify the cost of a new extrusion die.

Requirements for the various types of section are somewhat different, and may be outlined as follows.

Equal Angles. Plain equal angles become torsionally unstable with a leg-to-thickness ratio of about 12 to 1. This is too thin for economical design, and bulbs and a fillet are necessary.

A practical leg-to-thickness ratio is about 20 to 1, and as equal angles are commonly used in lattice work with slenderness ratios of over 50, the size of bulbs and fillet should be just sufficient to prevent torsional instability at this slenderness ratio. Bulbs of $3t$ diameter and a fillet of $3t$ radius have been found to be suitable.

Unequal Angles. The unsymmetrical nature of unequal angles makes it necessary to consider the possible interaction of flexure and torsion. Double unequal angles are, however, very economical in light lattice work, and should be so proportioned that, when used about a gusset, the moment of inertia of the composite strut is the same in both principal planes. For this, the leg lengths should be in a ratio of about 3 to 2, while for overall efficiency the ratio of longer-leg-length to thickness should be about 20 to 1. Stiffening similar to that on the equal angle should be sufficient to prevent torsional instability of a single angle when the strut is stitched at the third points.

Channels. Channels are mainly used as purlins or as double battened members, and for these purposes the depth should be about twice the width. Local flange buckling can be postponed by the addition of lips and fillets. Minimum practical thicknesses, governed by the extrusion process, appear to be about 1/30 of web depth, or 1/15 of flange width.

TABLE III.—PROPERTIES OF ALUMINIUM RIVET ALLOYS

Alloy	0·1% Proof Stress (tons/sq. in.)		Ultimate Tensile Stress (tons/sq. in.)		Elongation (% on 2 in. gauge-length)		Ultimate Shear Stress (tons/sq. in.)	
	BS.1476 (min.)	Typical	BS.1476 (min.)	Typical	BS.1476 (min.)	Typical	Typical Rivet Stock	Typical ⅞" Dia. Squeeze-Driven Rivets
N6M	8	9	16	18½	18	27	12	13·0 (single shear)
H10WP	15	18	18	20	10	13	14	14·5 (single shear)
H13T	—	10	BS.1473 17	19	—	20	12½	13·4 (single shear)

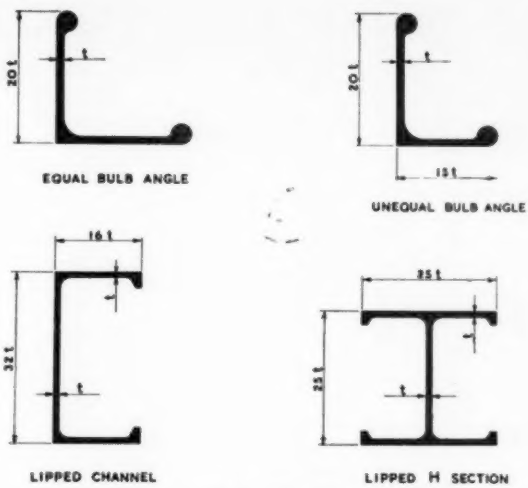


Fig. 10.—Form of efficient standard sections.

"*I*" *Beams.* As with channels, the main requirement is to stiffen the flanges against local buckling. Where "I" beams are used as struts, the sections should be squat, say with depth equal to flange width.

Fig. 10 shows the types of section discussed. Comparison with the current BS.1161 sections indicates that the newsections would be from 20 to 25% lighter for similar duties.

Joining

As a new material, aluminium presented some difficult joining problems, especially in the development of large aluminium rivets and in welding. Suitable techniques have now been established for most of the traditional methods of joining, and are in wide use. Mention should also be made of newer methods employed in some fields, such as gluing with synthetic resins.

Riveting. Riveting is the most satisfactory method of joining aluminium. Although hot-driven steel rivets have in the past been used in aluminium structures, they are not wholly suitable, and development has been directed towards large aluminium rivets, usually cold-driven. Table III shows properties of three rivet alloys.

It will be seen that there is little difference between the shear strengths of these alloys, and ease of driving is usually the deciding factor. The power required to close a cold aluminium rivet is greater than for an equivalent hot steel rivet, but smaller, specially shaped heads have now been developed for closing rivets up to ⅞ in. dia. with standard equipment, the holes being fully filled, provided that initial clearance is not more than $\frac{1}{32}$ in. Recommended heads for both squeeze and hammer driving are shown in Fig. 11.

In recent experiments, hot-driven aluminium rivets despite the narrow permissible temperature range and the high rate of cooling, have shown considerable promise.

In cold-riveted aluminium joints, owing to the lack of clenching pressure and the smoothness of the surfaces, frictional restraint is slight and the load is taken as shear in the rivets almost from the outset. Established methods of calculating joint strength are nevertheless quite safe, and it has been recommended that equal load distribution among rivets may generally be assumed

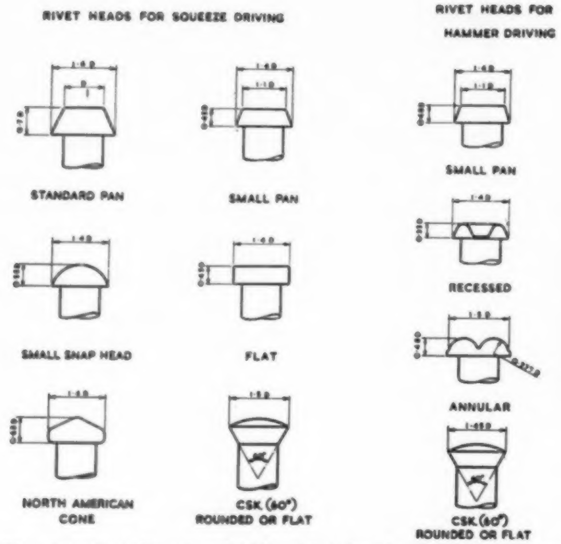


Fig. 11.—Details of suitable rivet heads for aluminium rivets.

provided that the joint has the following characteristics :

(1) Compatible with static strength, as ductile a rivet alloy as possible should be used. HE10WP is a most satisfactory alloy in this respect.

(2) Any plate alloy used should have a ratio of proof to ultimate stress sufficiently high to prevent plasticity of the plates within the joint before the maximum load is reached. HE10WP is one of the best alloys in this respect.

(3) The length of the joint should be as small as possible : i.e. as few rivet rows as possible for a given size of joint.

(4) Rivet pitches should be as small as practicable.

(5) Ratio of rivet diameter to plate thickness should be such that the rivet has as high a ductility as possible without any loss in rivet strength occurring. From the experimental evidence available for NE6 rivets a d/t ratio of approximately 1·5 appears to be the best.

Welding. Advances in welding technique have been such that perfectly reliable welds can be made in HE10WP without difficulty. The properties of the parent metal are, however, impaired in the vicinity of the weld, and until the mechanism of load transference in welded joints is more fully understood, really wide application of welding to structures will be held back. Nevertheless, many successful instances of welded structures are on record, and ultimately welding is likely to become of first importance.

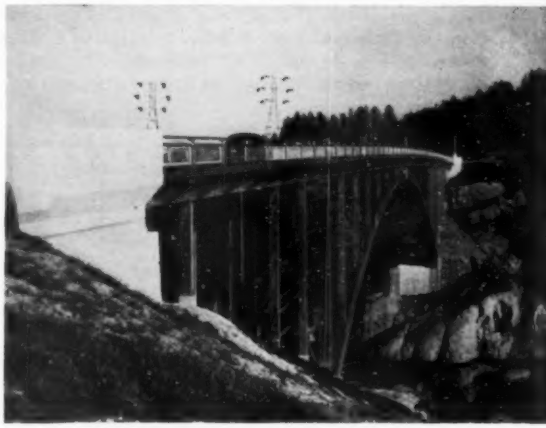


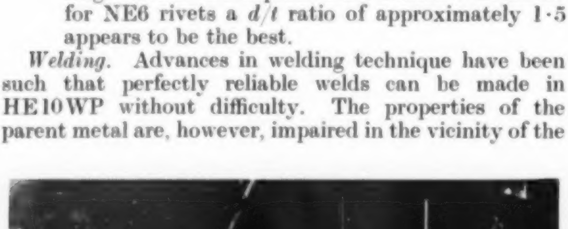
Fig. 12.—The Arvida aluminium bridge.

Recent Examples of Aluminium Structures

As aluminium is a fairly expensive material, some definite advantage must be gained to justify its use—for instance its high strength/weight ratio is of benefit in moving structures and in large-span buildings and bridges, while its durability has led to its use in corrosive environments.

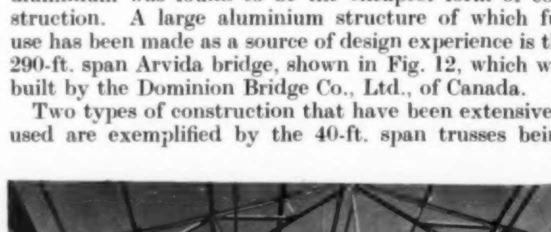
Examples of large-span structures include a hangar at London Airport, designed and built by Structural and Mechanical Development Engineers, in which each of the three bays has a clear span of 125 ft., the main portal-type arches being pinned at the base and built up from double battened channels, and a further 250 ft. span hangar, built elsewhere by the same firm, for which aluminium was found to be the cheapest form of construction. A large aluminium structure of which full use has been made as a source of design experience is the 290-ft. span Arvida bridge, shown in Fig. 12, which was built by the Dominion Bridge Co., Ltd., of Canada.

Two types of construction that have been extensively used are exemplified by the 40-ft. span trusses being



Courtesy of Structural and Mechanical Development Engineers, Ltd.

Fig. 13.—Aluminium roof trusses of double battened channel construction.



Courtesy of Structural and Mechanical Development Engineers, Ltd.

Fig. 14—Aluminium roof trusses of double angle construction.

Courtesy of Ove Arup & Partners.

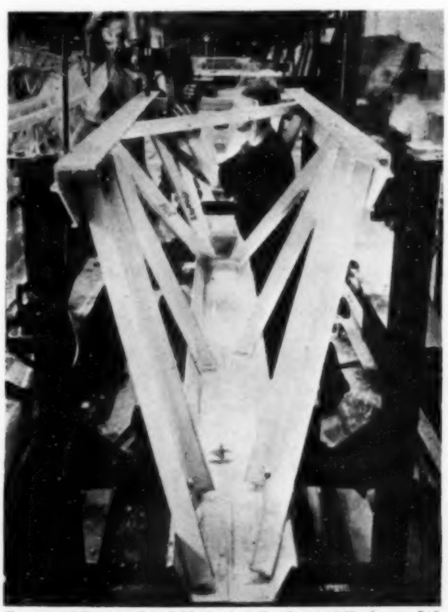
Fig. 15.—A section of the triangular roof truss used in the Duxford factory of Aero Research, Ltd.

built by S.M.D. Fig. 13 illustrates the doubie battened channel type, and Fig. 14 the double unequal bulb angle type. Though the former is lighter, the latter is more uneconomical when fabrication costs are taken into account. In the 42-ft. span truss designed by Ove Arup and Partners (Fig. 15) redundant framework is used to offset the low stiffness of the material. A similar type of truss was used in the Dome of Discovery (Fig. 16).

As an example of structures built to take advantage of the durability of the material, there is the 132 kV transmission tower shown in Fig. 17. It was designed by Blaw Knox, Ltd. for the British Electricity Authority, and in order to eliminate maintenance of the top of the tower, the top half is in HE10WP alloy. Legs and cross arms are bulb angles, with tubular bracing and HE10WP bolts are used for assembly. The prototype tower behaved well under the B.E.A. standard test.

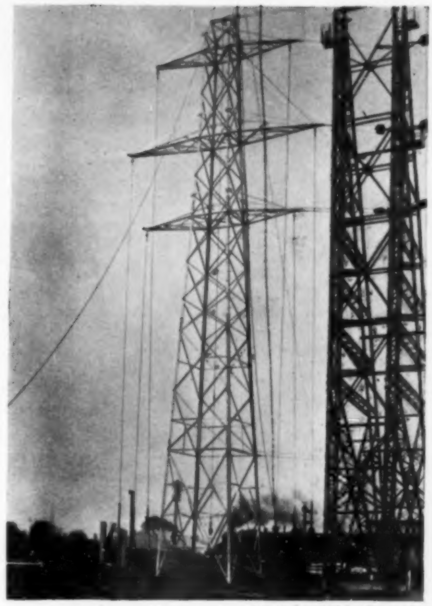
Conclusion

The scope of this article has deliberately been limited to the special aspects of design in aluminium; the majority of structural problems are, of course, common to all materials. It must be emphasised, however, that economical design of aluminium structures cannot be achieved unless the properties of the metal are exploited, and its limitations understood.



Courtesy of Structural and Mechanical Development Engineers, Ltd.

Fig. 16.—Construction of the triangular-section Dome of Discovery beams, showing the special sections used.



Courtesy of Blaw Knox, Ltd.

Fig. 17.—A 132 kV transmission tower, the upper half of which is aluminium.

British Technicians at Work in Indian Locomotive Factory Colombo Plan Aid

The Locomotive Manufacturers' Association of Great Britain is assisting the Government of India in the development of the Chittaranjan Locomotive Works in West Bengal. This Works is one of the projects of the India five-year plan, and the Association is assisting under a five-year agreement which provides for technical advice on the most efficient and economical methods of providing locos and boilers at Chittaranjan. The agreement includes the provision by the L.M.A. of skilled supervising and production staff for the works, and of facilities for the training of Indians in the workshops of U.K. manufacturers who are members of the L.M.A.; and the supply of equipment and components as required until the Chittaranjan works are in full operation.

A Technical Consultant provided by the L.M.A. visits the works about twice a year and a Production Adviser, formerly a Works Manager at the Doncaster Locomotive Works, is resident at Chittaranjan. Six British technicians supplied by L.M.A.—experts in boiler building, welding, locomotive frame erection and machine-shop practice—are also working there. The Government of India, through the Technical Co-operation Bureau of the Colombo Plan, in Colombo, applied further for the loan of the services of five operator-demonstrators, experienced in the handling of machine tools, and six rate-fixers. The U.K. Government agreed to provide this additional aid under the Technical Assistance Scheme. These experts, apart from three rate-fixers, are now at work in Chittaranjan.

General view of the Heat Treatment Division.

Induction Heat Treatment Plant

New EFCO Development at Burton-on-Trent

BELIEVING that there is a bright future for the induction heating of solid metals—whether it be for surface- or through-hardening, for heating prior to forging, or for brazing—Electric Furnace Co., Ltd. have recently completed at their works at Burton-on-Trent an extension which is devoted to research and development relating to induction heating, and which also provides facilities for heat treatment for the engineering industries.

The Burton works are situated on a two-acre site and comprise two sections—the Heat Treatment Division and a manufacturing works operated by the EFCO Engineering Co., Ltd. The Heat Treatment Division occupies a single bay 290 ft. long by 50 ft. wide and served by a 3-ton overhead crane. The H.F. generating equipment is housed in two sub-stations—the first having two 100 kW., 10,000 c./sec. motor-generator sets and an 80 kW., 2,400 c./sec. motor-generator set. From this sub-station, the high-frequency power is distributed by overhead busbars to a number of heater stations arranged down one side of the building and down the centre. The second sub-station houses three 210 kW., 8,300 c./sec. vertical axis motor generator sets feeding a group of three heater stations operated by the company on behalf of the Ministry of Supply. In addition, there are, in the open shop, a 20 kW., 5,000 c./sec. motor generator set and a 40 kW., 450 kc./sec. radio-frequency generator. The total connected load is 1,650 kW., with 950 kW. of high-frequency power available for research and production heat treatment. High-frequency current can be fed to each of 21 work stations, but, as a general rule, only one station operates from each motor generator. The water required for the cooling of inductors and transformers, and for quench purposes, is softened through Permutite softeners. It is stored in rock asphalte lined tanks under the floor, and is continuously recirculated and filtered. Any loss is made up from the town's water supply, which is softened before entering the storage tanks. Cooling plant is incorporated in the recirculating system, and motor driven pumps are used to give the requisite volumes and pressure of water for cooling and quenching.

Pins

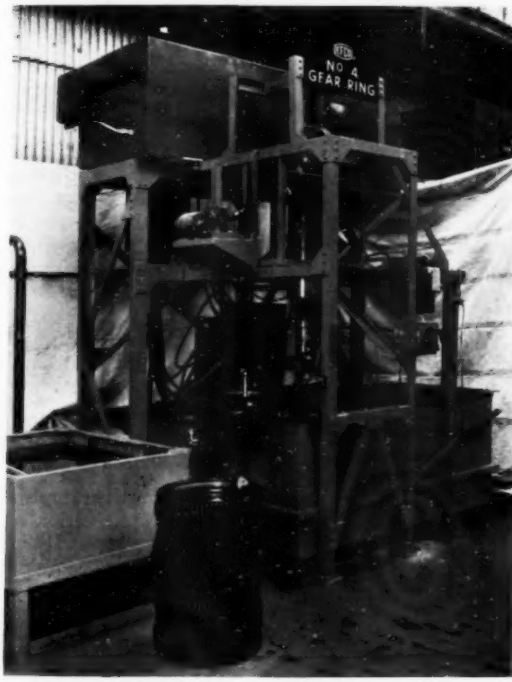
The induction method is seen to best advantage when large numbers of a particular component are to be treated, and considerable ingenuity is displayed in the design of inductors and handling equipment in order to ensure that the treatment, whether it be uniform or selective, shall be as specified. Three of the heat-treatment stations are available for the continuous surface hardening of steel pins, which are fed through the inductor by means of a roller box, the speed of feed being under control. The pins are spray-quenched immediately

Station for the hardening of shafts up to 40 in. in length.

below the inductor. Pins varying from 1 in. to 2½ in. diameter can be treated at two of the three stations, case depths of 0·050–0·150 in., or even more if desired, being attainable. The output may reach 600 10-in. × 1 in. diameter pins per hour. The third station is similar, except that pins up to 1 in. diameter only are treated.

Shafts

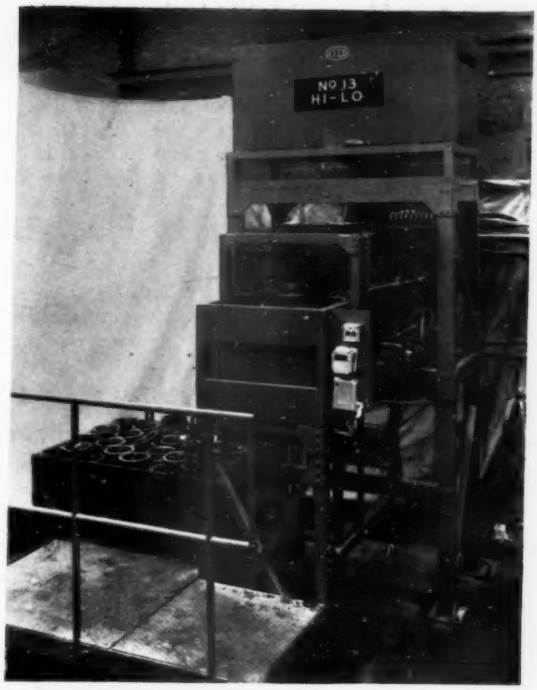
A further group of heat-treatment stations may be classed as dealing with shafts, which may be defined as parts from 1–3 in. diameter or more, and from 12–60 in. in length. There is obviously a certain amount of overlapping between the " pin " and " shaft " sizes, but the roller box method of feeding may not be suitable for shafts, owing to excessive weight or to variations in diameter along the length of the shaft. The usual method of treatment is to insert the shafts between vertical centres fixed to crossheads which slide up and down on guide bars, and so allow the shaft to pass,



Station for hardening large gear wheels and gear rims which are quenched in an oil bath.

successively, through the inductor and quench : the shaft may be rotated during treatment. Of the stations of this type, the largest can handle shafts of 60 in. length with diameters ranging from 1 to 3 in. Hardening can be stopped as desired to leave any portion soft : this is done by switching off the power while the shaft continues to move down at the same rate.

One vertical station has been designed specifically for the surface hardening of shaft collar faces. The area to be hardened is located in the inductor, and after heating is lowered rapidly so that the heated area descends into a spray water quench. A typical example is the surface hardening of cams, journals, eccentrics and camshaft drive gear on automobile camshafts. There is also a long stroke station for the continuous hardening of long



Hi-Lo station for hardening track roller tyres and gear wheels requiring a spray water quench.

plain shafts or plungers : the normal frequency is 10 kc./sec. and work up to 2½–3 in. by 60 in. long can be handled. For large heavy shafts there is a horizontal roller unit, whilst the splined ends of automobile or heavy vehicle half shafts can be hardened by insertion in a stationary coil prior to quenching in an oil bath.

Rings and Wheels

The Heat Treatment Division is also equipped for the treatment of ring- or wheel-type components and four stations are available for this purpose. One of these is designed for hardening, by the single shot method, the teeth on large gears or gear rings. The gears are preheated in a resistance furnace and placed on the loading carriage over a spigot. The carriage is pushed under the inductor where the spigot is gripped by a pneumatic ram and raised into the inductor. After heating for the pre-determined time, the spigot and gear are lowered on to rollers in an oil quench bath : the gear is rotated during both heating and quenching. The rollers transfer the gear into a basket at the other end of the bath where it may be raised for unloading.

Other two of these stations are of the Hi-Lo type illustrated and are suitable for treating cylindrical components of short length and large diameter, such as single flange track roller tyres. The tyres are loaded onto a spigot on top of a pneumatic ram, which lowers the tyre into the inductor for the requisite heating time, and then lowers it rapidly into a spray-quench, after which the operator removes the tyre and the spigot rises for re-loading. The component is rotated during heating and quenching. Gear wheels requiring a water quench, as opposed to an oil quench, can also be treated at this station.

The first machine on the right in the general view of the department is a special purpose unit designed primarily for surface hardening the working faces of the tread and flanges of double flange track rollers. The rollers are rotated in a hairpin-type inductor and, by means of the swinging arm on which the rollers are mounted, they are transferred after heating to the quench position. Two arms are employed so that, whilst one roller is being heated, another is in the quench position, and hence full utilisation of high-frequency power is achieved.

Miscellaneous

A typical application of the conveyor installation is the surface hardening of the working face of tractor track links. They are mounted in handling jigs and traversed, by means of a conveyor belt, under the hairpin-shaped inductor, where they are heated to the correct temperature before water spray quenching.

For work requiring treatment at frequencies of the order of 500 kc./sec. there is a general purpose station fed by the radio-frequency generator referred to earlier. Typical examples of work treated here are small components which require to be hardened by the single shot method to a shallow case depth over a limited area, and the continuous surface hardening of small pins or plain shafts. Internal hardening of cast iron cylinder liners by the scanning method is also done on this station.

Although the main application of induction heating has been the hardening of steel components, a considerable amount of brazing with copper and other brazing metals has been carried out in this way. The 5,000 kc./sec. station, in which the heating rate is slower than that on other stations, is successfully used for this purpose, and the operation can be carried out in a hydrogen atmosphere, when necessary.

In a separate enclosure are a number of stations where experimental work is carried out on new types of components before hardening is done on a production basis.

Aluminium Laboratories Extension

An important increase in the research facilities of the aluminium industry is marked by the completion of the first stage of the extensions to the Banbury premises of Aluminium Laboratories, Ltd. The Company, which is the research and engineering organisation of the Aluminium, Ltd. Group, operates laboratories at Kingston and Arvida in Canada and a design office at Geneva, in addition to the Banbury laboratories which are adjacent to the plant of their associated company, Northern Aluminium Co., Ltd.

The full scheme, to be completed by mid-1954, will increase the floor area threefold and the present extensions have more than doubled the available accommodation by the addition of a large laboratory wing to the existing buildings and the erection of a new experimental block. This expansion of research facilities runs parallel with the Aluminium, Ltd. Group's development of productive capacity as typified by Northern Aluminium Company's continuous strip mill at Rogerstone and by Aluminium Company of Canada, Ltd.'s large-scale expansion programme at Kitimat, British Columbia.

The new buildings were designed by Sir Percy Thomas, P.P.R.I.B.A., and Son, and incorporate a number of novel features, including a central hollow wall running the whole length of the laboratory block providing a vertical and uninterrupted duct on two floors in which all services are carried. Space heating is by aluminium panel ceilings with incorporated flush lighting and accoustical correction. Much use has been made of aluminium for windows, pitched roof trusses and coverings, partition framing, rainwater fittings and metal trim generally.

A full description of the new buildings will be published after completion of the scheme.

Geared Motor Order

In the face of keen competition from American companies, David Brown & Sons (Huddersfield), Ltd. have secured a £15,000 order from the Aluminium Co. of Canada, Ltd., the world's largest producers of light metal. The order, which was negotiated by the Huddersfield firm's Canadian associate, David Brown (Canada), Ltd., of Toronto, covers the supply of 350 " Coventry " geared motors (size 2½). These units, a standard product of the Coventry Gear Co., which was acquired by the David Brown organisation in 1944, give a choice of 17 output speeds ranging from 25 r.p.m. to 345 r.p.m. with input powers from 0·25 h.p. to 2 h.p.

The geared motors covered by the Canadian order will be used to raise and lower the electrodes employed in the reducing furnaces at the vast aluminium smelting plant which the Aluminium Co. of Canada, Ltd. is building at Kitimat, 400 miles north of Vancouver. Begun in 1948, this plant will eventually be capable of producing over half a million tons of aluminium a year. A few miles away, an entirely new city is being built to house 7,500 employees and their families. When the plant is operating at full capacity Kitimat will have a population of 50,000 and will rank as the third largest city in British Columbia.

Honeywell-Brown Expansion Move

Because of the increasing demand for their products, coupled with an extensive forward production programme for both existing and new ranges, it has become necessary for Honeywell-Brown, Ltd. to move to premises two-and-a-half times as large as their present factory at Blantyre. The new factory is situated on the Newhouse Industrial Estate at Motherwell, Lanarkshire and extends over an area of 75,000 sq. ft.

In planning the move, the utmost care was taken to ensure that continuity of production will be maintained. The new factory will therefore be taken over during the annual shut-down—the last two weeks in July—and workers will return from their holidays to find equipment installed and " ready to go " at Newhouse. The proximity of Newhouse to Blantyre has been a valuable asset to management when considering problems thrown up by the move. One of the most important of these was the retention of their existing work-people, the majority of whom will find Newhouse—which is well served by public transport—as readily accessible as Blantyre.

The ultimate increase in the Company's productive capacity will mean that the number of its employees will eventually be doubled. The range of Brown Industrial Instruments will be augmented, and new production is planned for Honeywell products such as heating and air-conditioning controls, for which new plant has already been purchased.

Metal Casting Methods

IV—Ferrous Ingots

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World production of steel greatly exceeds that of any other metal, and by far the greater proportion of it is cast into the form of ingots for subsequent hot working by forging or rolling. After dealing briefly with the casting of pig iron, the author proceeds to a consideration of some of the problems involved in ingot production and their solution.

PRIOR to 1896, all pig iron produced in the world was cast into sand moulds. The latter were simple shallow depressions which were formed in a sand bed prior to tapping the blast furnace. Large numbers of such pig moulds were prepared in rows, all the pigs in each row being connected at one end to a larger channel, known as the sow, which in turn was fed with molten iron from the main runner leading from the furnace. As soon as one row was filled the dam in the main runner was removed and the metal allowed to flow on to the next row, and so on. Much time and labour was required to prepare the pig beds, and a considerable time lag existed between the completion of one tapping cycle and the time when the pig beds were available again. Moreover, a great amount of heat was radiated from the pig iron during cooling, which rendered working conditions very difficult. The slow cooling conditions which existed, delayed the use of magnet crane equipment for handling the pig iron owing to the length of time elapsing before the latter had cooled sufficiently to become magnetic. As blast furnaces became larger, the casting problem became more acute, as the amount of metal obtained at each tap was so great in many cases that considerable extensions of pig beds were required. As the open-hearth process developed, the hot-metal technique became established, and simplified the metal disposal problem to some extent. Furthermore, several mechanical devices were developed to facilitate pig mould production, but the principal disadvantages remained, namely, the slow cooling rate and the excessive area occupied by the pig beds.

Pig Casting Machines

In 1896, Uehling developed the pig casting machine in the U.S.A. This device consisted essentially of an endless chain bearing a series of cast iron permanent moulds. In practice, the chain and mould assembly were moved in a horizontal direction by mechanical means, so that each mould could be filled in turn from a stream of liquid iron directed from a lip-pouring ladle. The endless chain passed over two sprockets, one of which was placed at each end of the system. When each filled mould reached the end of the line, and passed over the sprocket, the solid pig was deposited into a waiting truck. The inverted mould then passed back to the central pouring station, and was sprayed with a protective coat of limewash in transit. Casting conditions were mainly controlled by the weight of pigs required, and the casting cycle was operated in such a manner that each pig was solid before the mould concerned was inverted. Chain speeds were relatively high when small pigs were needed, and comparatively low when pigs of maximum size were required. In order to avoid excessive lengths of casting chain, twin and triple chain systems were developed. These were operated at standard speeds and supplied with liquid iron simultaneously from a divided launder or pouring channel.

Courtesy of Stanton Ironworks Co. Ltd.

Mould assembly on pig casting machine.

Pig casting machines are now standard equipment in all modern blast furnace plants of large capacity, though smaller furnace plants of older design still use sand bed casting methods. One early disadvantage of the machine casting system was that the existing method of pig iron classification by fracture became useless. The characteristic appearance of fractured pig irons of various types is only developed in slowly cooled material, and machine cast pig tended to give nondescript fractures owing to the rapid cooling conditions under which it was produced. Modern practice is based upon chemical analysis rather than fracture, and the earlier disadvantage is not now regarded as serious. Machine cast pig iron is clean, being free from adhering sand, and all pigs in a particular batch are of comparable weight. The machine casting system can readily handle 100 tons of pig iron in 20 minutes, and pig bed making, magnetting, pig breaking and loading are all avoided when machine methods are used. Similar casting methods are used for the production of refined pig irons on a large scale from cupola-melted material. Small scale casting plants have also found application in the production of lead and zinc ingots, and for certain aluminium alloy ingots intended for remelting purposes.

Steel Ingots

More than 90% of the total world steel production is cast into ingots for subsequent mechanical working. Such ingots range from a few pounds in weight to over 200 tons, according to the type of steel produced and the purpose for which it is intended. Complex steels, intended for high-speed tools, are frequently cast into small ingots, while ingots weighing more than 100 tons, and occasionally more than 200 tons, are cast for forging into large high pressure boiler drums. The bulk of steel ingots are subsequently rolled into sections or plates for structural work and will usually weigh less than 5 tons each. Ideally, steel ingots should be cast into the shapes most suitable for the treatment which follows ; no single ingot design is suitable for all purposes and many designs have been proposed in order to utilise a given mass of steel to the best advantage.

Cast iron is the standard ingot mould material, and the moulds are simple hollow castings of appreciable wall thickness. Mould wall thickness is important, since it must be sufficient to freeze rapidly the liquid steel as the latter rises in the mould. The steel skin temperature must be reduced below the melting point of cast iron, and so avoid the possibility of fusion occurring between ingot and mould. When the skin is formed, it increases in thickness relatively rapidly until it contracts away from the mould wall, when the rate of solidification is slowed down by the presence of the air gap between ingot and mould. Another factor of importance is the shape of the ingot mould, as this can have a bearing on the cracking of ingots. This is of most consequence in the case of the high carbon steels, which are more susceptible to cracking. Ingot cracks may result from a number of causes, but in many of these restraint of the contraction of the ingot whilst red hot is the important factor.

Steel ingots produced in the early days of the industry were small, and seldom exceeded 200 lb. in weight. Ingot size was limited by the small capacity of crucible steel melting units, and killed steel was invariably made. Huntsman adopted the principle of " hot topping," in order to prevent shrinkage occurring in the ingot, and segregation was then not a problem. When large-scale steelmaking methods were introduced, segregation, piping and gas evolution increased in importance. Crucible steel was originally restricted to applications such as edge tools, and killed steel is still recognised as the best material for this purpose. As engineering techniques improved, it was seen that other types of steel could be applied to greater advantage in constructional work, and three main steel types are now recognised ; these are the killed, semi-killed, and rimming varieties. The main distinction is probably the gas content of each type, and the effect this factor has upon freezing and segregation.

The Solidification of Steel

The solidification of steel was first systematically studied by Brearley[1], and by Gathmann[2]. Both of these workers used model ingots cast in stearine wax which enabled solidification phenomena to be studied. It was not possible, however, to investigate segregation or gas evolution. Fetters and Dienes have more recently used silver chloride ingots for experimental work, and segregation studies were carried out by suspending non-metallic material in the molten compound prior to casting. It is claimed that the plastic nature of silver chloride is an additional advantage, if deformation tests are required. Gas evolution and segregation can only be studied in a satisfactory manner by the use of full-sized steel ingots. Much useful work has been carried out by the Joint Heterogeneity Committee of the Iron and Steel Institute and the Iron and Steel Federation[3]. The fact that no less than nine reports have been published, the first more than 25 years ago, indicates the magnitude of the problems arising in a study of ingot structures. This work is not yet completed, and certain features of segregation still remain to be clarified. Killed steel ingots have been studied extensively, since the absence of gas evolution during solidification promotes comparatively undisturbed freezing. Crystal formation is affected to some extent by gas evolution in rimming steel ingots. The type of crystal structure formed in any steel ingot will influence the response of such material to heat treatment and mechanical working processes.

Molten steel may be simply regarded as a solution of several elements in iron, and when this material begins to freeze, progressive and selective crystallisation is likely to occur. This results in segregation of certain elements on both a macro and a micro scale. There are also present in molten steel particles of slag and other non-metallic compounds resulting from deoxidation procedures. These particles tend to rise to the top of the ingot but many of them are trapped by the freezing metal and further segregation effects arise in this way.

Killed Steel Ingots

The influence of the mode of freezing is seen in both the crystal structure and the extent and type of segregation present. In a typical killed steel ingot, there are three zones of crystals merging into each other. A narrow zone of so-called " chill crystals," which are equi-axed, surrounds a thicker zone of long columnar crystals which are nearly perpendicular to the mould walls. Small interlocked dendritic crystals occupy the remainder of the ingot structure. Pouring conditions and chemical composition have a pronounced effect on ingot structure, high casting temperatures and rapid teeming rates promoting columnar crystallisation to such an extent that the columnar zone may extend to the centre of the ingot—a structure which is not the best for subsequent working. On the other hand, cold moulds and low casting temperatures increase the thickness of the chill layer of crystals. Northcott[4] has shown that the crystal size is markedly influenced by the pouring method used, as may be seen from the results set out below for experiments using five different pouring techniques. The figures are the length (in inches) of the columnar crystals at the mid-length position of 1,680 lb. steel ingots.

Bottom Cast	Single Cast	Multi-hole Tundish Cast	Cast with Stream down Side		Tilted Mould	
1·9	1·45	1·55	0·9	0·7	0·6	3·5

The effect of subsequent hot-working by rolling or forging is to improve the crystalline structure and to tend to equalise some of the heterogeneity by diffusion. It is not possible, however, to get rid of the segregation of non-metallic inclusions by such means, although there may be a certain amount of breaking up of large segregates, and some of the inclusions such as manganese sulphide may be elongated into threads by rolling.

A number of different types of segregation can occur in killed steel ingots, including V-segregates, A-segregate

and ingot corner segregate. The first named is associated with the axis of the ingot, which has a tendency to be unsound due to the mode of solidification, and is so called because on a sulphur print of a longitudinal section of an ingot it appears as a series of V's. The A-segregate results from the action of the columnar crystals in pushing inclusions towards the centre as they try to rise to the top, being eventually trapped between the columnar crystals and the central equi-axed crystals. This segregate appears between the axis and the outside, being nearer the axis at the top than at the bottom. Ingot corner segregation occurs as a result of inclusions being trapped between the columnar crystals growing from one face of an ingot mould and those from an adjacent face. Owing to the shrinkage which takes place on solidification there is a tendency for a long axial cavity to form at the top of the ingot, and there is usually appreciable segregation associated with it. The use of feeder heads, etc., for restricting the extent of the cavity formed will be referred to later.

Rimming Steel Ingots

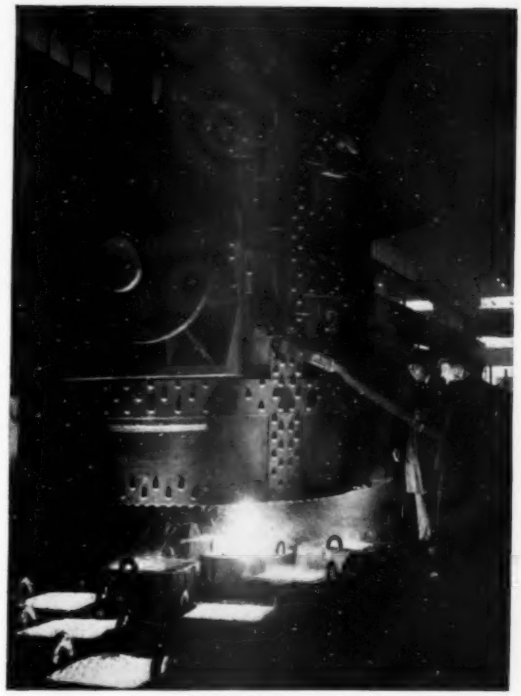
Sinking of the top of the ingot and the formation of a pipe cavity can also be prevented by the evolution of gas during solidification. In rimming steel ingots, the pipe cavity is replaced by blowholes in the body of the ingot so that there is no need to discard the top of the ingot in order to remove the pipe. The gas evolution results from the interaction of carbon and oxygen in the steel. High carbon steels do not contain sufficient oxygen to produce large volumes of gas, and rimming steels are, therefore, usually of low carbon content. The mechanism of blowhole formation in rimming steel ingots has been outlined by Hultgren and Phragmen[5].

In order to obtain satisfactory results it is necessary to control the oxygen content of the steel to ensure that the gases are liberated in the most suitable manner, and thus cause the blowholes to be located well beneath the skin of the ingot. There should be a good solid rim of steel which is free from blowholes, and almost a complete absence of pipe. The blowholes, being well below the surface, are welded up during the early stages of hot rolling. A reduction in the amount of discard is not the only advantage of rimming steel ; the solid outer rim of the ingot contains less carbon and sulphur than the average percentages for the ingot as a whole and, therefore, when used in the manufacture of sheets and strips improved stamping qualities are obtained. It follows, of course, that the amounts of impurities in the central zone exceed the average values for the ingot.

Between the killed steels and the rimming steels are the semi-killed steels, in which no gas evolution occurs until the carbon and oxygen increase (in the last remaining molten metal at the top centre of the ingot) sufficiently for gas evolution to occur. In this way the pipe cavity is replaced by a zone containing blowholes.

Shrinkage and Piping

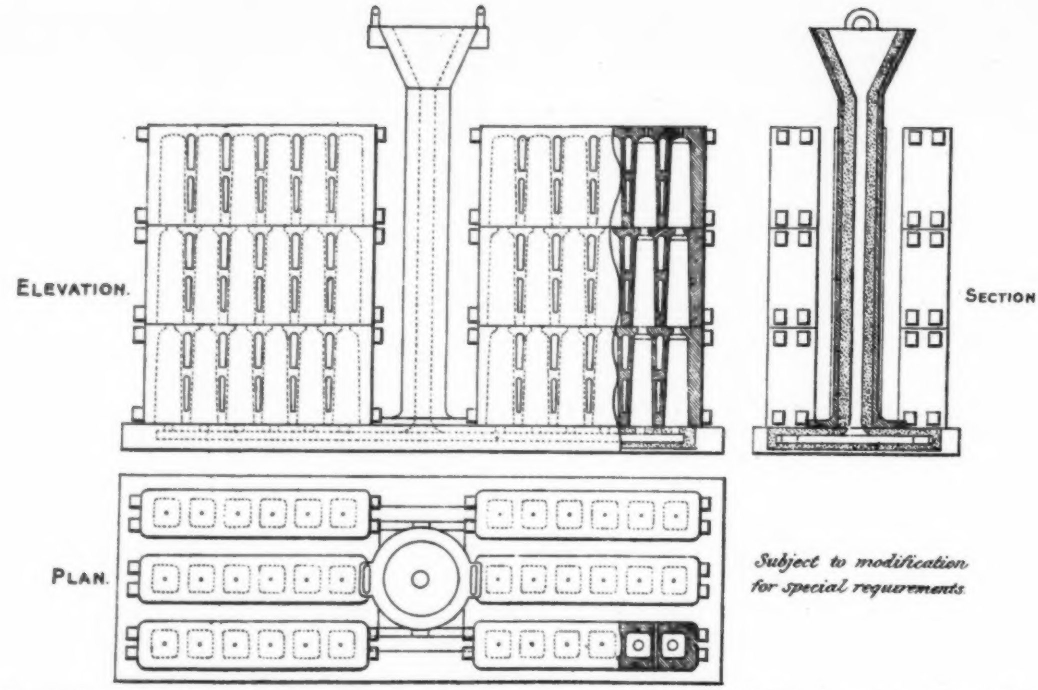
Shrinkage or pipe in steel ingots has always been a major problem, and early workers were mainly concerned with the economic aspects of the matter. The work of Gathmann and Brearley was directed towards the development of improved ingot designs which were capable of giving higher yields than those previously obtainable. The original cast iron ingot moulds in general use were of the big-end-down type. Each mould was a simple hollow casting open at both ends, and provided with sufficient taper to promote separation of the ingot after solidification was completed. In practice, each mould rested upon a cast iron slab called a mould stool which could accommodate one or several ingot moulds at the same time. As the size of the steel ingots tended to increase, shrinkage defects became more pronounced. Piping was encountered in rolled or forged steel despite the fact that considerable proportions of the original ingots were cropped and discarded during an early stage of the hot working process. Huntsman had successfully applied the "hot topping" principle, using refractory-lined feeder heads, to small crucible steel ingots, and thereby raised the piped portion out of the main body of the ingot. Hot-topped big-end-down ingots were somewhat better than the ordinary type, though some "secondary piping" was occasionally encountered. The latter defect, caused by solid metal bridging the ingot before the whole of the metal below it was solid, appeared as local unsoundness, situated in the lower part of the ingot and apparently separated from the primary pipe by a limited thickness of sound metal. Various devices were suggested, and the group casting of large numbers of small ingots as developed by Turner was perhaps the most striking of these. The principle is illustrated, and is similar in many respects to that long used in sand foundry practice for stack moulding purposes.



Courtesy of Round Oak Steel Works Ltd., and Saga Services.

Teeming steel ingots.

Gathmann and other workers established that secondary pipe formation could be avoided, if ingots having reversed taper were cast. Big-and-up moulds were therefore, designed, and proved technically superior to those previously used. Stripping was a more complicated operation, as big-end-up moulds were



Turner's patent system of casting ingots. Arrangements for casting 108 ingots from one runner pipe.

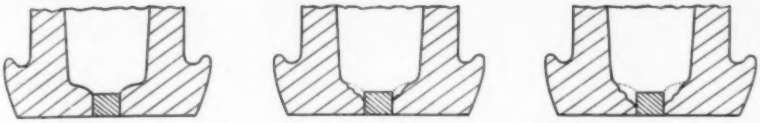
equipped with solid bases; the ingots were, therefore, removed from the moulds, instead of vice-versa. Ingot stocks were maintained in many cases, as it was not always possible to use them immediately after casting. When big-end-down ingots were cast, they could be left on the original stools until required, and the moulds freed for further use. Big-end-up ingots, however, required separate storage owing to their shape, and it was not always convenient to mark such ingots for future identification. These disadvantages still exist and large tonnages of ordinary steel ingots are produced in big-end-down moulds, despite the difficulties which have been discussed.

Teeming Methods

Lip-pouring methods were originally used for crucible steel ingots and the practice is still widely used, but Bessemer introduced bottom-pouring ladles, in order to effect good metal—slag separation during the casting of large ingots. This technique proved adequate and is almost universally used for teeming steel ingots. In using Bessemer-type ladles, a jet of molten metal is directed into the ingot mould from the top, and the considerable force of the metal stream resulting from the relatively large head of metal contained in the ladle, may lead to mould erosion. If big-end-down moulds are used, the cast iron stool receives the impact of the stream, and mould wear is minimised, but big-end-up moulds are directly attacked by this method of teeming, and the amount of mould erosion which occurs can be readily correlated with the ferro-static head in the ladle.

Modified techniques have been suggested, including the use of a pad of steel wool in each mould, to act as a shock absorbing medium during the teeming operation, and tundish methods have been widely used in order to obtain relatively quiet casting conditions. A tundish is essentially a metal container, usually rectangular, which is refractory lined. In effect, the container is supported above the mould or moulds, and filled with molten steel from the suspended ladle. Single or multiple nozzles are situated in the bottom of the tundish, allowing streams of liquid steel to enter each mould, under gravity; such methods are also believed to reduce cracking in large ingots. Refractory-lined pouring baskets attached to the base of the Bessemer-type ladle, have also been used, enabling lip pouring to be practised, while still keeping the slag in the ladle.

Big-end-up moulds are now most often used for high quality steels, and are fitted with detachable plugs. Each mould is designed so that a cast iron or refractory plug may be inserted in the base. In principle, the molten metal stream is directed on to the plug, and mould erosion is thereby minimised. The ingot is stripped, and the plug detached, before the former is transferred to the soaking pits. The system is useful, but limitations have appeared in practice. It is extremely difficult to direct the metal stream on to the mould plugs, since the ladle crane driver is usually thirty or forty feet above mould level, and his view is frequently obscured by the ladle contour. Mould erosion is, therefore, liable to occur in the areas adjacent to the plug; the plug may then be surrounded with liquid metal, and subsequent removal will be difficult. Big-end-up ingots may be soaked in the inverted position, owing to the difficulty of supporting them in an upright position. If the cast iron plugs are entrapped in the ingot bases, and the ingots soaked, the plugs may partially melt at normal soaking pit working temperatures, flowing downward over the ingot surfaces and rendering the material defective. Refractory plugs tend to break if separation is difficult, and the remnants can be the cause of scrap in the rolling mills.



New mould with base intact. Mould after 50 heats. Mould after 120 heats—base badly eroded.

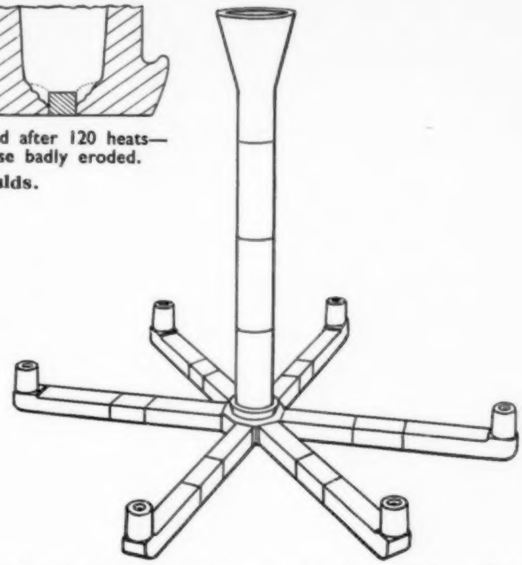
Progressive mould erosion in big-end-up moulds.

Uphill Casting

Modern high-quality steels are frequently cast uphill, and this system is believed to be due to Pink, an Englishman employed in the Hoerde works in Germany. Pink's ascension casting method, as it was known, was originally practised in 1872, and is still widely used with very little modification. The technique was developed to avoid the high percentage of defective material sometimes obtained from moulds filled from the top. Such ingots may have surface defects due to metal splashes impinging on the mould walls, or to poor mould surfaces caused by metal erosion. Big-end-up ingots are especially liable to the latter defect, and the writer has established that the proportion of defective rails, billets, etc., obtained from rolled big-end-up ingots, steadily increases as the mould life is extended. Such defective material is confined to billets, etc., which have been rolled from blooms taken from the lower third of each ingot. These findings have since been confirmed elsewhere. In uphill casting, the moulds are arranged round a central " trumpet," which is a vertical refractory runner surmounted by a refractory funnel. The bottom of the runner is connected by horizontal refractory runners to the base of each ingot stool. Uphill casting is more expensive than other methods, since it involves much preliminary work on runner preparation, and mould assembly, and stripping is slow and arduous. The product is excellent, however, so far as ingot surface is concerned, and mould life is greatly extended. Large ingots may be cast singly, by the uphill method, while very small ingots can be successfully produced in large numbers. Uphill casting technique requires higher casting temperatures, since the liquid steel must traverse a comparatively great distance through the refractory runner system. The liquid metal is also inevitably cooled as it rises in the ingot mould. In the uphill casting system, the metal contained in the " hot top " or upper portion of each mould will tend to be somewhat cooler than that in the lower part. Premature freezing may occur under such conditions, and secondary piping is possible unless exothermic preparations are used to prevent it.

Compression Techniques

Various methods have been suggested in order to reduce the amount of shrinkage or pipe occurring in large steel ingots. In 1856, Bessemer attempted to apply pressure to steel ingots during solidification, but the first practical method was probably that due to Whitworth in 1865. Harmet[6] proposed the application of a compression technique to ingots which had been vertically cast. Similar work was carried out by Robinson and Rodger in 1906, some four years later. The latter workers believed that compression could be applied horizontally to the best advantage, while Harmet concentrated on vertical compression techniques. In 1912, Hadfield[7] developed a technique which was successfully applied to both small and large ingots. The normal



Refractory runner tube assembly for uphill casting.

" hot top " was lined with sand, and the assembled mould filled with liquid steel to within 3 or 4 inches of the top. Ground cupola slag was placed on the surface of the molten metal, and a layer of charcoal superimposed. A compressed air blast was directed on the surface of the charcoal, and considerable heat was developed owing to the oxidation which occurred. The slag layer was rapidly fused, and functioned as an insulator, and the steel was not then liable to rapid heat loss or carbon pick-up. In 1913, Talbot[8] proposed to subject partially solidified steel ingots to compression by ordinary rolling ; though this method was relatively efficient it proved to be somewhat dangerous in practice. If the system was used after solidification was virtually complete, piping was not prevented. When compression was applied to incompletely frozen ingots, it was possible for the surface to be fractured, and liquid metal ejected with considerable force. These limitations also apply to the alternative processes in which compression is applied.

Feeder Head Compounds

The high cost of equipment and the difficulties inherent in operation have restricted the general application of these processes. Modern practice is based upon the application of exothermic or insulating powders in the hot top of each ingot. Such powders may be of many different types, and the application and efficiency of these preparations has been reviewed by Gregory[9]. Large ingots and shaped castings are frequently rendered sound by arc feeding methods, which involve the striking of an electric arc between a small suspended carbon electrode and the liquid steel contained in the top portions of the ingot or casting. Arc feeding is also applied to the production of cast iron rolls, and wholly sound castings can thereby be obtained with a minimum of feeding metal. Secondary piping is still possible, unless adquate precautions are taken to prevent bridging.

Influence of Mould Material

Shrinkage porosity, blowhole formation, and piping tendency, are all affected to some extent by the type of

Torrington mould ready for casting.

Torrington mould opened for ingot removal.

mould material used for ingot production. Mould materials of high thermal conductivity will exert some influence upon the soundness of ingots, and, in general, moulds of this type will have a considerably longer life than those of ordinary construction. Thick-walled grey cast iron moulds will have a greater heat storage capacity than will the thin-walled variety ; heat abstraction from the ingot will be initially rapid, and the formation of a sound skin will be facilitated. Thick-walled ingot moulds are preferable where a rapid casting cycle is practised, and a smaller ingot mould stock is required to cope with a given furnace output. Such moulds are limited, as all moulds are, by the useful life of the working face. When the latter has deteriorated to such an extent that good ingot surfaces are no longer obtained, the ingot mould must be scrapped, since no economic repair method is available. Thin-walled moulds are, therefore, increasingly used for steel ingot production ; efficient life is obtained by the use of larger mould stocks and a planned casting cycle. Pure copper and graphite mould stools have been used on a limited basis for steel ingot production[10,11] ; open type moulds of big end down design are utilised, and extremely long stool life is obtained. Secondary piping tendency is reduced, no doubt owing to the directional solidification which occurs. Binnie[12] has studied the effect of casting rimming steel into copper moulds, grey cast iron moulds, and partially refractory-lined moulds.

Modern practice is based upon the production of relatively large ingots which are hot worked into the required shape. Structural steel is produced from fairly large ingots which are cogged or slabbed according to whether they are to be rolled into structural shapes or plates. Thin strip may be produced by continuous rolling methods. Continental practice has favoured the casting of slab- or bloom-sized ingots, which are economical, and may be hot rolled directly into the desired shape. The initial breaking down stage and subsequent reheating are thereby avoided. During the recent war, the alloy steel shortage led to the casting of billet-sized ingots from electric melting units, and this system was most successful.

Mould preparation has received much attention in the literature dealing with this subject. Various preparations have been tried in order to extend mould life. Boiled tar, aluminium paint, and soot, have all been used, together with numerous proprietary mixtures of a carbonaceous nature. There appears to be little advantage attached to the more expensive preparations, and it seems that almost any product of a semi-refractory nature wili serve the purpose. Mould working temperature is of greater importance, and a good stock of moulds should be maintained, so that the casting load is spread evenly over all. Large ingot moulds invariably have shorter working lives than do the smaller variety, mainly due to the greater thermal capacity of large ingots, and the extended time for which the moulds are exposed to elevated temperatures.

The increasing cost of cast iron has stimulated interest in ingot mould costs. The latter cannot be assessed accurately in most cases, since ingot mould life cannot be precisely estimated. In general practice, the useful working life of an ingot mould is thought to be reached when ingot surface conditioning costs become excessive. There are many cases, however, in which only a small portion of the mould surface is defective. Such moulds can only seldom be reconditioned, and for all practical purposes mould life is dependent upon the maintenance of a flawless mould face. It is likely that hot-rolled steel products are subjected to considerably more mechanical work than is actually required to produce a desirable microstructure, and slab-sized and billet-sized steel ingots have been produced in the industry when local conditions rendered it economic to do so. It is remarkable that the water-cooled mould which has been so successful in the non-ferrous field has not found application for the production of steel ingots.

The Torrington mould illustrated is in continuous use for the production of brass slabs for rolling purposes. Each slab weighs approximately 1,100 lb., and is rapidly poured by means of the multi-hole tundish provided. Water circulates continuously behind the mould faces and solidification occurs so rapidly that the slab can be withdrawn from the mould five minutes after pouring is completed. The use of copper-faced water cooled moulds of almost unlimited life would seem to offer one solution to the present steel ingot mould cost problem.

REFERENCES.

1 Brearley. "Ingots and Ingot Moulds." 1918.
2 Gathmannn. U.S.A. Patents 1909 onward.
3 Iron and Steel Institute. Reports on the Heterogeneity of Steel Ingots.
4 Northcott. *Journal Iron and Steel Institute*, 1941, **143**, 49.
5 Hultgren and Phragmen. *Trans. A.I.M.M.E.* 1939.
6 Harmet. *Journal Iron and Steel Institute.* 1902.
7 Hadfield. *Journal Iron and Steel Institute.* 1912.
8 Talbot. *Journal Iron and Steel Institute.* 1913.
9 Gregory. *Journal Iron and Steel Institute.* 1940.
10 Williams and Kinnear. *Metals and Alloys.* 1935, 6.
11 Black. *Iron and Steel Engineer.* 1949, 26.
12 Binnie. *Journal Iron and Steel Institute.* 1949.

The Institute of British Foundrymen

Fiftieth Annual Conference at Blackpool

The interest taken in this the fiftieth annual general meeting of the Institute of British Foundrymen, recently held at Blackpool, was of a high order and compared favourably with previous annual meetings of the Institute. In addition to the business meeting, the social and technical activities were admirably organised and supported. A very full programme had been prepared but only brief reference can be made here to the business meeting and the technical sessions.

THE Fiftieth Annual Conference of the Institute of British Foundrymen, recently held at Blackpool, was the fifth Conference to be held under the auspices of the Lancashire Branch. Blackpool was chosen because the Winter Gardens in that town provides unique facilities for holding the various meetings and social functions. A very full programme had been prepared, commencing during the afternoon of June 16th, with Council and Committee meetings at the Imperial Hotel, and followed in the evening by a Reception and Dance, by invitation of the Mayor and Mayoress of Blackpool, held in the Windsor Lounge and Spanish Hall of the Winter Gardens, at which the Mayor extended an official welcome to members and their friends.

The Annual Meeting proper was held the following morning in the Baronial Hall of the Winter Gardens with the President, Dr. C. J. Dadswell, in the Chair. The initial item on the agenda was the presentation of the annual report of the Council, which was unanimously approved by members. The President directed attention to the growing membership of the Institute, which now exceeds 5,000, and called upon Mr. N. P. Newman, the Hon. Treasurer, to present the balance sheet.

The President particularly welcomed the Victoria Division of the Institute of Australian Foundrymen, which has amalgamated with the British Institute and will be known as the Australian Branch (Victoria) of the Institute of British Foundrymen.

Report of the Technical Council

The twenty-first annual report of the Technical Council was presented by Mr. A. E. Peace, who emphasised that although only one sub-committee had completed its work during the year it did not reflect any diminution in the activities of the Council or its sub-committees. Four other sub-committees have reached advanced stages of their work and will submit their reports early in the coming year. It is of interest to note that co-operation has continued during the past year with the British Cast Iron Research Association, the British Steel Castings Research Association, the British Non-Ferrous Metals Research Association, the Light Metal Founders Association and the Association of Bronze and Brass Founders. A similar liaison has developed with the Technical Committee of the British Bronze and Brass Ingot Manufacturers Association, who have contributed to the work of two sub-committees.

The work of the Technical Council depends for its success on the many members who have advanced the aims of the Institute by taking part in technical sub-committee work and also the many firms who pursue the policy of allowing members of their staffs to attend meetings and to carry out experiments in their laboratories and foundries, and the Council records its sincere thanks to these for the help received.

Presentation of Awards

The next item on the agenda was the presentation of the 1953 awards to members in recognition of outstanding work in forwarding the interests of the foundry industry. The President presented the Oliver Stubbs Medal to Mr. G. W. Nicholls, of the West Riding of Yorkshire Branch, in recognition of the outstanding quality of the many papers, largely of a practical nature, which he has presented to the Institute, and for his contributions to the technical development of foundry practice.

On the recommendation of the assessors, the Council awarded the E. J. Fox Medal to Sir Wm. Larke, K.B.E., in recognition of the great help and encouragement he has given to the foundry industry in many capacities. In the absence of Mr. Fox the presentation was made by the President, who read a letter from Mr. Fox expressing his pleasure that the award should be made to Sir William.

The award of the Meritorious Services Medal was made to Mr. Harold Haynes in recognition of his active and exceptional work, over a long period, for the progress of founding and in imparting his knowledge to others.

The British Foundry Medal and Prize of £10 was presented to Mr. D. F. B. Tedds, of the Bristol Branch, in recognition of the excellence of his paper, entitled "Experiences with the Investment Casting Process," published in the recently issued volume of the Institute's Proceedings.

In each case, the recipient of the award replied and expressed his thanks, in suitably chosen words, for the honour conferred upon him.

As a result of recommendations from branches, the Council awarded diplomas to the following authors of papers presented during the past session :—

Mr. J. R. Jones for his paper, "Production of Ingot Moulds by Sandslinger," presented at the Buxton and Sheffield Conference.

Messrs. J. M. Douglas and M. S. Richardson for their paper, "The Practical Application of Some Modern Ideas in the Brass Foundry," presented to the Scottish Branch.

Mr. D. H. Potts for the paper, "Aluminium Pressure Cast Match Plates," presented to the Birmingham and London Branches.

Messrs. J. H. Pearce and C. D. Whitehouse for their paper, "Casting Design in Relation to Production," presented to the Scottish Branch.

Election of Officers

The retiring President, Dr. Dadswell, after referring to the career of Mr. E. Longden and speaking of him as one of the most eminent and highly-respected foundrymen in this country, inducted him as President for the year 1953–54, and invested him with the chain of office. Mr. Longden has gained a wealth of experience in his long career in the foundry industry and in expressing appreciation of the honour conferred upon him, he said he would do his utmost to emulate the good work of his predecessors in office.

Mr. John Bell and Dr. Arthur B. Everest were nominated, and unanimously approved by the members, as Senior- and Junior Vice-Presidents, respectively, and invested with their chains of office, while Mr. N. P. Newman, J.P., was re-elected Hon. Treasurer. The result of the ballot for the election of Members of Council, to serve for the two years ending June 1955, was announced as follows: Messrs. J. Blakiston, V. Delport, P. A. Russell, G. R. Shotton and R. Yeoman. Messrs. J. Hird and E. M. Currie will serve until June 1954.

Presidential Address

It is typical of Mr. Longden that he should base his presidential address on "Science, Technology and Craftmanship" for his long and wide experience, from the foundry floor to works manager and now a consulting foundry engineer, has enabled him to study the relationship between science and technology and between technology and craftsmanship, particularly in connection with foundry work, and his views are widely appreciated. The main features of his address are presented elsewhere in this issue, so that readers can have an opportunity of reading his views without comments here.

Edward Williams Lecture

The Council of the Institute are to be congratulated in persuading Mr. E. W. Colbeck to deliver the Edward Williams Lecture which he presented on "Aspects of Nuclear Fission of Interest to Foundrymen and Metallurgists," particularly because of the interesting and informative manner in which he dealt with what is often regarded as a very difficult subject. After distinguishing himself at Cambridge, Mr. Colbeck commenced his metallurgical career as a junior scientific officer in the Metallurgical Department of the National Physical Laboratory in 1922. In 1924 he became technical assistant to the general manager of the Openshaw Works of Sir W. G. Armstrong Whitworth & Co., and took his M.A. in 1927. He joined the Research Department of the Alkali Division of Imperial Chemical Industries, Ltd., Northwich, in 1928, becoming chief metallurgist to this division and consulting metallurgist to several other divisions during the period 1928–1947. In 1945 he was loaned to the Department of Atomic Energy as metallurgical adviser to the director of research, Sir John D. Cockcroft, and the controller of production, Lord Portal. During this period he was chairman of the metallurgical committee dealing with uranium metal production. In 1947 he returned to the heavy steel industry when he became the metallurgical and research director to the Hadfield Group of Companies. A report of the Edward Williams Lecture appears elsewhere in this issue.

Technical Sessions

In addition to a Report of Sub-Committee T.S.38, fourteen papers were presented, from which considerable discussion resulted. In addition, films were shown, which had been prepared by the Research and Development Division of the British Steel Founders' Association and the British Cast Iron Research Association; these were concerned with the suppression of foundry dust, a subject to which considerable attention has been given during recent years. There were six sessions and the number of papers presented at any one session did not exceed three. As the time allocated for discussion was short the usual practice of holding two sessions simultaneously was again adopted, sessions A and B being held on the Wednesday afternoon and sessions C and D and E and F being held the following morning and afternoon, respectively. The exchange paper from the American Foundrymen's Society was on "Shell Moulding," while the French exchange paper was concerned with "Modification Methods for High-Silicon Aluminium Alloys and their Influence on Structure."

Lack of space prevents a complete report of the proceedings at these sessions, but in the following notes are given some of the main features from the papers, and the Report, presented at this meeting.

SURVEY OF THE SHELL-MOULDING METHOD OF CASTING PRODUCTION

By Bernard N. Ames

This official exchange paper from the American Foundrymen's Society summarises and surveys the shell-moulding process, sometimes referred to as the "C" process, and is based primarily on data developed in research and production activities at the New York Naval Shipyard. This process, during the last few years, has been recognised as one of the major technological advancements in the foundry industry.

The raw materials currently used in this process are washed and dried silica sands or bank sand containing a small percentage of clay and a "B" stage phenol-formaldehyde resin. The process has opened a wide avenue of investigation on the utilisation of numerous types of moulding materials. In many instances it may be feasible and economical, in order to achieve certain properties, to deviate from the use of silica sand as a basic moulding medium and to employ other basic materials.

The amount of resin employed is approximately 5–9% by weight of the sand used, and is dependent upon the sand fineness and the amount and fineness of the additive employed. Sands which are being used for this process range in A.F.S. fineness from 75 to 230 and are either round, angular or sub-angular in grain shape. The clay content should generally be under 3% and the sand should be low in metallic oxides or fluxing agents. Sands with a wide grain distribution (five to six screens) seem to yield superior finishes, and as a rule the finer the sand the smoother the surface of the resultant casting.

The paper was introduced by Mr. Harris who referred to it as the most important contribution on the subject in this country. Included in the paper are data on the mechanics of the process, metallurgical evaluations of the process, detailed information on pattern equipment, gating and heading, dimensional tolerance, mould closing and cores; attention is also given to mechanisation and

to plant safety and applications and economics of the process are freely discussed. The author concludes that the process, when used in the proper application, is an economical foundry technique which permits the use of cheaper labour, frequently improves metal yield, and reduces cleaning costs and machine-shop time.

SHELL-MOULDING PROCESS

By D. N. Buttrey, M.Sc., A.R.I.C., A.P.I.

It was rather unfortunate that Mr. Buttrey should have been called upon to present his paper after that by Mr. Ames, because translation of the process to the production scale in this country has been slower than in the United States. However, both these papers should be carefully studied by those interested in the application of the process. Mr. Buttrey is of the opinion that a considerable background has been built up on the process, and satisfactory techniques both for the making of shells and for casting into them have been established. Factors such as influence of sand particle-size and type of resin binder on shell properties, separating agents, pattern materials and pattern and oven temperatures have been investigated, and many data are now available. The main advantages of the shell-moulding process over conventional sand-moulding techniques are: (*a*) superior finish of castings; (*b*) closer tolerances on casting; (*c*) ease of casting thin sections; (*d*) lowered surface chilling of metals; (*e*) reduction of blowing; and (*f*) reduced after-machining costs. These properties are of particular interest to the motor and aircraft industries, for the casting of engine components, and it is in these industries that the most rapid progress is expected in applying shell-moulding. Reduction of finishing costs and of reject rates on certain types of castings can more than offset higher moulding costs, without taking into account the other advantages offered. Size of castings is, to date, a limiting factor, and, in addition, the type of individual work done by jobbing foundries is not suited to shell-moulding. It is expected, therefore, that the process will become established firmly in the internal combustion engine industries and will be used on a considerable scale for all types of precision components; that in a number of industries, e.g., textile machinery, pumping equipment, electrical components, etc., it will be used for a wide variety of specialised casting requirements; and that in jobbing foundries, making larger castings for heavy equipment, it will find comparatively little application.

The large number of members present for the presentation of these two papers on shell-moulding indicated the extent of the interest in the subject, and considerable discussion resulted, much of which was of an inquiring nature rather than critical comparisons with established methods.

PELLETED FOUNDRY PITCH

By E. Brett Davies, T. F. N. Matthews and G. Smart

Reports of British technologists, following visits to the United States after the war, on the use of pulverised coal-tar pitch as an additive to foundry sand, led to an investigation of American foundry practice. This showed that in many cases considerable benefits were being obtained, for the most part in stove-dried and skin-dried work, by incorporating some 1–3% of finely ground coal-tar pitch with the foundry sand. The use of this ground pitch was claimed to have a dual purpose in that it replaced coal-dust and, by virtue of its volatile content, gave an excellent surface finish to castings, while the agglutinating property of the pitch bound together the sand particles during stoving and gave enhanced dry-strength to the moulds. This paper, introduced by Mr. Davies, deals with British applications of pitch for foundry purposes. Reference is made to the origin of coal-tar pitch, its properties and chemical composition, and particular attention is directed to its general foundry applications with regard to green-sand moulding, dry-sand moulding, skin-dry moulding and core production. It is claimed that the use of pitch is more easily controlled than coal-dust. Medical aspects and costs are other questions discussed and there is an Appendix which gives the basis of the method recommended by the British Cast Iron Research Association for the determination of pelleted pitch in moulding sand.

EFFECT OF HEAT ON CLAYS AND ITS BEARING ON THE "LIFE" OF CLAY BONDS

By S. Davison, B.Sc., and J. White, D.Sc.

All clays, when in their normal "air-dried" condition, lose water on heating. This water is of two kinds: (*a*) adsorbed water, and (*b*) chemically-combined moisture which is formed as a result of the loss of hydroxyl groups present in the clay mineral as an essential part of its structure. The loss of adsorbed moisture, which takes place largely at 110° C., and to a less extent at temperatures slightly above this, is generally completely reversible, i.e., in a humid atmosphere the moisture lost will be picked up again and the clay will be found to have changed little if at all in its properties. The loss of chemically-combined moisture generally begins at temperatures over 400° C., and is essentially complete if sufficient time is allowed at temperatures of the order of 550°–700° C., depending upon the nature of the clay. This loss is accompanied by a breakdown of the clay structure and is, therefore, irreversible since the clay cannot, under normal conditions at least, be reformed. It is accompanied by almost complete loss of the ability to become plastic with water. The effect of heat on all clays is thus ultimately to destroy their bonding properties. This will always happen to the clay in a mould in the immediate vicinity of the mould/metal interface, where the temperature is high enough to decompose the clay completely and almost instantaneously. There exists in the mould, however, a much deeper zone where the maximum temperatures reached lie between say 400° and 700° C., in which the time/temperature conditions are such that clays with different dehydration characteristics may be expected to show appreciable differences in the degree of breakdown they will undergo during a given cycle of use. This might reasonably be expected to be reflected in differences in the "life" of the clay bond in service. The object of the investigation reported in this paper was to determine whether such a relationship between breakdown characteristics and "life" did in fact exist, and to ascertain to what extent such differences in behaviour could be correlated with changes in the chemical and physical properties of the clays during heating.

At the outset of the work it was realised that all the principal types of clays should be included in the investigation, and, in view of the emphasis on the use of bentonite in foundries showing considerable differences

in "life," it was considered essential to study as many minerals of this type as possible. Routine examination of bonding clays from many sources in the Refractories Department of Sheffield University showed that the bentonites examined fell into two groups, and it was decided to include three of each type in the work. The clays finally selected being plastic kaolin, Newton Abbey ball clay, Wyoming bentonite, commercially treated Italian bentonite, Greek bentonite, Pembina bentonite, North African bentonite, and natural Fullers' earth.

In so far as green-strength can be considered to provide an index of "life," it would appear from this work that the latter is determined mainly by the dehydration characteristics of the clay, and that an assessment could be made in the case of bentonites from such indirect tests as differential thermal analysis, moisture-loss characteristics or the variation of base-exchange capacity with temperature.

EFFECT OF MOULD RESISTANCE ON INTERNAL STRESS IN SAND CASTINGS

By R. N. Parkins, B.Sc., Ph.D., and A. Cowan, B.Sc., Ph.D.

Residual stresses in castings can arise from temperature differences in various parts of the casting and from volume changes accompanying phase transformations, but in this paper attention is directed more particularly to those that result from resistance by the mould. The authors have carried out some experimental work designed to assist in the study of the effect of the sand in hindering the contraction of the metal.

Measurements on castings of simple shape indicate that the surrounding mould material may offer considerable restraint to the casting as it cools, and that the degree of restraint is, in general, related to the high-temperature strength of the sand. It is inferred from this result, that the frequent suggestion that the mechanical properties of the mould have little influence upon the formation of residual stresses is not always true, depending upon the shape of the casting and the alloy concerned. It is shown in an Appendix that the stress remaining in a cast rectangular framework can be controlled to some extent by the use of a facing sand, on various parts of the casting, having a grain-size distribution resulting in close packing of the grains.

GROWTH CHARACTERISTICS OF INGOT-MOULD IRONS IN AIR AND VACUUM

By J. W. Grant, A.M.I.Mech.E.

Growth in cast iron is the permanent increase in volume that occurs when the material is subjected to an elevated temperature. Many attempts have been made to explain this phenomenon but none adequately accounts for all the anomalies encountered. Two factors that cause growth when cast iron is heated to temperatures in the vicinity of its critical temperatures are: (1) decomposition of carbides and pearlite with the consequent deposition of graphite; and (2) oxidation of the metallic matrix causing the formation of bulky oxides. Apart from these, there are theories regarding the formation of cracks due to differential expansion and contraction, and the part played by dissolved gases and gases that have penetrated the metal during the early stages of growth.

In this paper, the author discusses these theories and then reports the results of his study of the oxidation products and growth of ingot-mould irons caused by long heat-treatments at 500° C. in air, and repeated heating 650°/900°/650° C. in air and vacuum. In the vacuum tests, growth of as-cast and vacuum-annealed ingot mould iron continued at a fairly uniform rate according to the number of heatings. A volume growth of 80% was obtained after 300 heatings, 650°/900°/650° C. Pure iron/carbon and pure iron/aluminium/carbon specimens that were melted, cast and tested in vacuum had grown 44 and 153%, respectively, after 300 heatings and were still continuing to grow. Annealing in air inhibited growth due to repeated heating in vacuum. The growth after 300 heatings in vacuum was completely arrested by annealing in air at 700° C. for 20 hours.

The results of this work gives strong support to the cracking theory. Annealing in air appears to cause a protective envelope to form around the graphite, which prevents the solution of graphite in the gamma iron at the austenitising temperature, and thereby diminishes the intensity of the expansion and contraction during the $\alpha \rightleftharpoons \gamma$ transformation.

PRODUCTION OF DIESEL-ENGINE CASTINGS IN GREY IRON

By J. R. Charlton

In this paper, the author describes in detail the production of diesel cylinder blocks in cast iron. Although the castings described are not large they are complicated and since castings of this type had not previously been made in the foundry of which the author is works manager, considerable thought had to be given to their production. The engine frame first described combines in a single casting, the cylinder block and crankcase. Eighty-five cores were used in making the five-cylinder unit, and ninety in the six-cylinder unit. The respective weights being 2 tons 11 cwts. and 3 tons.

In the case of castings of this size and complexity, planning of production is essential; indeed, the making of the casting should be carried through on a theoretical basis before the pattern is started, and, as emphasised by the author, the co-operation of all concerned is necessary to obtain satisfactory results. However, all the planning in the world will not produce a good, sound casting without the applied skill of the individual pattern-maker, moulder and coremaker. The author's record of procedure in the production of the castings described is both interesting and informative.

INTER-RELATION OF COMBUSTION AND METALLURGICAL REACTIONS IN THE CUPOLA

By D. Fleming

The author of this paper believes that the cupola, which has undergone so many variations of a transient nature in the past, is now emerging into a period of development of greater significance than ever before, and feels that a restatement of some of the fundamentals of cupola behaviour and presentation of some of the remaining problems is justified at this time. He refers particularly to the trend away from the conventional cold-blast, acid-lined cupola for the quantity melting of soft grey iron as an indication of the changes taking place.

In surveying the large amount of work that has been done on the cupola, he cites the cupola behaviour diagram, based on experimental data, of Jungbluth and

Korshan as a starting point. This is examined and shown to relate CO : CO_2 ratios to C : Fe ratio independently of blast volume (the errors of classical methods of blast-volume computation are thus exposed). The effect of C : Fe ratio, coke size, and blast temperature are considered and the mechanism of combustion indicated. The concept of a reaction temperature is introduced, together with synthetic and experimental curves ; the deduced zone behaviour is compared with the results of Vogel.

Reactions possible in the shaft of the furnace are then considered, followed by similar considerations for the melting zone and hearth, the fundamental importance of high temperature and low iron-oxide production is pointed out, together with the importance of the control of slag/metal reactions. An ideal is suggested for soft grey iron, and it is claimed that the necessary control can be obtained, using a combination of hot-blast, water-cooling, and continuous tapping. It is claimed that such a cupola would allow soft grey iron to be economically produced without the need for pig-iron, should supplies of ferro-alloys, and iron and/or steel scrap be available.

" FOUNDRY " DEVELOPMENT IN THE TEXTILE INDUSTRY

By B. Gale

The group of companies represented by the author, Textile Machinery Makers, Ltd., covers the manufacture of every machine necessary for the production of yarns of every type from the " gin " to the spinning frame. All the subsidiary companies have long standing business in textile machinery of well over 100 years and formerly operated independently. The group was formed in the early 1930's and through co-ordinated management, a degree of specialisation has taken place, different companies now specialising on certain classes of machinery instead of each making the full range. The Group now operates twelve foundries with a combined output of some 46,000 tons of light castings a year, representing millions of castings from thousands of patterns.

The demands of spinning call for the highest skill of fine-tolerance engineering from the pattern to the finished machine, so as to run threads at very high speeds without breakage. For instance, a typical spinning frame may have 400 spindles, each revolving at 12,000 r.p.m. with complete absence of vibration. The many types of yarn manufactured, coupled with the individual demands of the mill technicians, creates numerous variables of the same type of machine ; thus the machines cannot be mass-produced. When all technical details of a mill or machine are settled and pattern equipment made, the thousands of castings required are divided into various classes of foundry production. Since certain parts of a machine are special to that order, others may be repeated on different orders, and some are common to all frames, the production control staff are always faced with small lots, medium lots, and large quantity production, and must plan for different methods of production, from loose-pattern moulding to fully-mechanised plants, involving versatility on the part of the foundry staff.

Since the Group was formed, considerable development has been effected, and to-day the general run of small types of castings is produced by the usual mechanised foundry plants, and while each of the foundries is normally occupied on castings for its own particular Company's products, the management have had fullest investigations into standardisation of moulding boxes, plates, etc., to enable easy transfer of work from one foundry to another.

The author makes comparisons between the methods of production formerly employed and those in operation to-day, and goes on to describe the metallurgical aspects of melting and metal control, referring to the composition of cast iron used normally, and also to special compositions, commenting particularly on the unusual cupola layout. Some useful information is given on the utilisation of borings, which had been given considerable study before evolving a satisfactory method of reclamation.

Several firms in the Group have up-to-date, well-equipped laboratories for the testing of incoming materials and the controlling of works processes, whose major function is the carrying out of these services in the foundries. The compositions of all pig-iron supplies are checked and tests are carried out also on incoming scrap, coke, etc., to provide the basis for computing cupola mixes.

ECONOMIC UTILISATION OF COPPER-BASE ALLOYS

Report of Sub-Committee T.S.38

Acute shortages of non-ferrous materials have emphasised the need to conserve valuable raw materials, and the Technical Council of this Institute appointed a Sub-committee to investigate the properties obtainable in copper-base alloy castings, with a view to the economic utilisation of these materials. As consideration of the object proceeded, it became clear that the properties obtainable in castings constituted only part of the problem, and other factors, such as the standardisation of alloys and methods of production, were of equal importance. The terms of reference have, therefore, been interpreted in the broadest sense, with the emphasis on the economical utilisation of metals ; the investigation on the properties of copper-base alloy castings is in progress but the work is not ready to be reported.

The present report is divided into four main parts : the first two consider the steps which can be taken by the foundryman and the user respectively with advantage to both ; the next deals with the properties obtainable in castings ; and the last with the standardisation of alloys. These are followed by a statement of the conclusions reached. In most respects, the reference to the foundryman concerns both the die-casting and the sand-casting sides of the foundry. Similarly, from the users point of view, it is frequently economic for him to use die-castings rather than sand castings, and appropriate reference is made in the text of the report to the use of die-castings.

EFFECT OF POURING CONDITIONS ON SHRINKAGE UNSOUNDNESS IN BRONZE INGOTS CAST IN METAL, CARBON OR SAND MOULDS

By W. T. Pell-Walpole, D.Sc.

In previous work, it has been established that the extent of shrinkage porosity in gas-free bronzes cast into cast-iron moulds depends mainly on the rate of pouring. Porosity is least when the rate of pouring is

the minimum which will fill the mould without cold-shuts: when this rate is used, variation of the temperature of pouring has little effect, but, at higher rates, variation of pouring temperature has more effect than variation of rate. The work reported in the present paper is an investigation of the effect of rate and temperature of pouring on the soundness of bronze cast into moulds of widely differing thermal characteristics, namely, metal moulds, carbon moulds and sand moulds.

As a result of the investigation, it is concluded that pouring rate has an appreciable effect on the extent of shrinkage porosity in castings only when the mould material used has a high chilling power, so that solidification is rapid. In practice, therefore, control of pouring rate can be used to control the soundness of castings made in metal moulds, carbon moulds or water-cooled moulds, but not of sand castings. With chill ingot moulds, which give the required rapid rate of solidification, maximum soundness in the ingot is obtained by pouring at the lowest rate which will fill the mould without the formation of cold-shuts. When solidification takes place very rapidly, as with chill ingot moulds and slow pouring rate, variation of pouring temperature has little effect on shrinkage porosity. On the other hand, with sand castings, when solidification is prolonged, pouring temperature is one of the most potent factors affecting the extent of shrinkage porosity. It is shown that for any given set of pouring conditions, the density of a casting of any section varies directly as the chilling power of the mould material, and, since foundry sands have very low chilling power, sand castings commonly exhibit more shrinkage porosity than chill-cast ingots. In addition to the improvement in bulk-density obtainable by using materials of higher chilling power, a possible application is the use of materials of different chilling power for moulding adjacent sections of different thickness when these are so positioned that efficient feeding of the heavier section is impossible.

DIFFICULTIES IN THE PRODUCTION OF CENTRIFUGALLY-CAST NICKEL-BRONZE BEARING SHELLS

By J. Taylor, Assoc.Met., Z. Stokowiec and R. S. Jackson, B.Sc.

Among the many alloys produced by the centrifugal method, a nickel-bronze alloy has presented unusual difficulties in manufacture. One major problem, the investigation and solution of which is described in this paper, demonstrates in an acute form a hazard that is of minor consequence in many more-easily-produced materials.

The castings in this particular alloy are produced in the form of two sizes of shells for babbitt-metal-faced diesel-engine bearings by the horizontal-axis centrifugal method, the alloy being leaded nickel-bronze. The occurrence of pin-holes in the facing was traced to slight porosity in the base metal. During the metalling process, gases, whether trapped in the pores or derived from flux, form bubbles in the babbitt metal which, on subsequent machining to the finished size, leave depressions in the surface. It is believed that this interdendritic porosity in the backing metal is due to gas evolution in the later stages of the solidification of the copper/nickel/tin matrix, and that this gas forces the lead, which is still liquid, out of the regions in which the evolution occurs. Methods of preventing the original solution of the gases included avoidance of the use of gassy ingots; the addition of small quantities of titanium; melting under an oxidising flux and inert-gas scavenging of the molten metal, but all these methods proved unsuccessful. Other modifications to the process, including changes in the pouring temperature and speed of rotation of the casting machines had little effect. It was found, however, that by careful adjustment of the conditions of cooling, it was possible to eliminate the porosity entirely, and to reduce the segregation due to micro-banding to negligible proportions.

FEEDING OF STEEL CASTINGS AT GREATER-THAN-ATMOSPHERIC PRESSURES

By Charles W. Briggs and Howard F. Taylor

This Report was prepared from a research study, carried on at Massachusetts Institute of Technology for the Steel Founders' Society of America, to determine the effects of the application of greater-than-atmospheric pressures in the risers of steel castings.

As a result of the investigation, no dependable improvement in feeding efficiency, as evidenced by casting quality or increased yield, was found as a result of using gas pressures in excess of atmospheric in side/blind or top/blind risers. From isolated cases of successful application, it is apparent that pressure-feeding of 3–50 lb./sq. in. are more beneficial than higher gas pressures. Low positive gas pressure on casting riser systems prevents cope defects, but this could be accomplished by increasing sprue size in order to ensure a positive pressure against the cope surface until adequate skin has formed. The rate of application of gas pressure is extremely critical, particularly when green sand moulds are used. Control of temperature gradients remains as the paramount consideration in making sound castings, and is of equal consequence with or without the use of high gas pressures. "Pressure capsules" made of zinc pellets in graphite cylinders produced sound castings in isolated instances, but their performance was not dependable. The control of gas pressures by the application of nitrogen to the riser were more ideal than could be produced by the use of pressure capsules.

MODIFICATION OF HIGH-SILICON ALUMINIUM ALLOYS AND THE CORRESPONDING STRUCTURES

By Claude Mascre, Ing.E.P.C.I.

This is the official exchange paper from the Association Technique de Fonderie Francaise. It deals with the action of phosphorus and sodium on hyper-eutectic aluminium/silicon alloys, on which research work has been carried out in the central laboratory of the Centre Technique des Industries de la Fonderie. Results of tests show that phosphorus reacts on aluminium to form particles of aluminium phosphide which play the part of nuclei of crystallisation for the silicon; the fineness of the resultant structure attains its maximum for an addition of 0·01% of phosphorus and this is associated with higher mechanical strengths. Sodium, by increasing the viscosity of the liquid aluminium, changes the silicon crystals from a geometric form, first to one of dendritic character and then to globular. These structural modifications reduce the mechanical strength of the alloy.

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Aspects of Nuclear Fission of Interest to Foundrymen and Metallurgists

By E. W. Colbeck, M.A., F.I.M.

The following is an account of the Edward Williams Lecture presented by Mr. Colbeck to the Annual Conference of the Institute of British Foundrymen held at Blackpool last month. In it he discussed four aspects of nuclear fission of interest to foundrymen and metallurgists, namely : non-destructive testing ; tracer techniques ; nuclear energy as a source of power ; and constructional materials for atomic piles.

IT has been said that a new era in warfare was opened that August day in 1945 when the first atomic bomb was exploded above the town of Hiroshima. I believe that we should provide a counter-statement of far greater import by saying that the pioneer work of Rutherford, Cockcroft and Walton, Hahn and others has started the Atomic Age in which developments of incalculable good for mankind will take place.

A very similar sentiment was expressed by Mr. Williams himself at the conclusion of his Presidential Address to your Institute in 1933, when he expressed the hope that the discovery of aluminium alloys, though potentially of such importance in war might lead to an era where, so he said, wars and rumours of wars came to an end.

I do not propose to re-state the basic facts about nuclear fission, nor to give you a disquisition on atomic piles, nuclear reactors, atomic explosions and the like. I would refer those of you who wish to study such matters to the so-called " Smyth Report "[1], to Sir Wallace Aker's May lecture to the Institute of Metals in 1947[2], and to Sir John Cockcroft's James Clayton Lecture to the Institution of Mechanical Engineers[3]. Though relatively old, these three references are still outstanding in providing a clear picture of the fundamental problems involved.

The metallurgy of uranium and its alloys is a closely allied subject, which is fascinating in its complexity, but here again I feel there is need to follow the main theme and to content myself with a brief reference to two recent publications which give some account of the occurrence, metallurgy and properties of this metal. The first is a paper I gave to the London Branch of the Institute of Metals[4] and the second an article by Dr. H. M. Finniston in *The Times Science Review*[5].

Even after this extensive elimination, I find myself embarrassed by the magnitude of the field which is covered by the title I have chosen. I intend to deal with the subject under a number of main headings, which are briefly as follows :—

(i) Non-destructive examination by means of radio isotopes.
(ii) The use of radio isotopes as tracers in metallurgical processes and in physical metallurgy.
(iii) Nuclear energy as a source of power.
(iv) Some problems connected with constructional materials for atomic piles.

Non-Destructive Testing

Of the three types of discernible radiation emitted from radio isotopes, only gamma rays, which in nature resemble exactly the familiar X-rays, penetrate metals sufficiently to be useful for the radiography of castings. Though in the course of my description of gamma radiography I shall claim that the advent of these isotopes is causing something approaching a revolution in technical foundry control, we must not lose sight of the fact that radiography is not a new technique.

X-rays were discovered before the turn of the century ; but the field lay almost dormant for ten years after the original six weeks of feverish experimental work by Röntgen, in which he carried out all sorts of crucial tests with the new rays he had discovered, including the shadow radiography of metallic objects. Then in about 1908 the medical profession started radiography in earnest ; X-ray diffraction was discovered by von Laue and the Braggs in 1911–13. Five years later, the pioneer work for radiography in the foundry was carried out by Sir Robert Hadfield, Dr. Main and their collaborators at the Hadfield Research Laboratories. Even to-day their papers[6] make quite remarkable reading, in that most of the major applications of radiography were clearly foreseen.

Since then it has been found possible to examine by X-rays the internal soundness of castings of ever increasing complexity and section thickness. During the past ten years X-ray equipment has been extensively used for the non-destructive testing of steel castings—especially aircraft castings upon whose soundness depend the lives of pilots. In Fig. 1 is shown the most modern method of radiographing such castings—in this case undercarriage pivot brackets. They are seen jigged with fixed angulation for simultaneous radiography by a central radio isotope source of gamma radiation.

But even gamma radiography is not entirely new. Its potentialities have long been appreciated because of the ready portability of the necessary equipment for site radiography of heavy castings, and because one can put gamma sources at inaccessible places within castings where it would be impossible to position an X-ray tube. In our own laboratories we have, in fact, been using natural radium and radon gas sources of gamma rays for the last five years. Radium tends to give somewhat

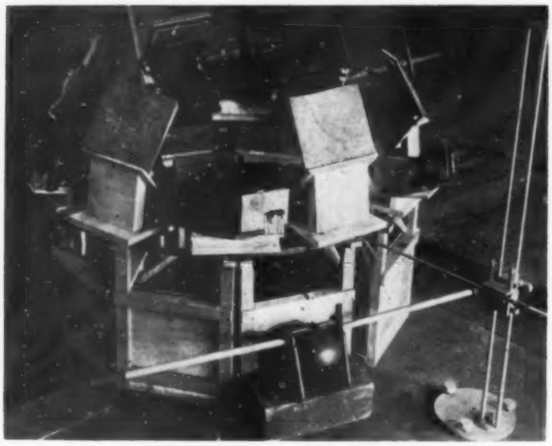


Fig. 1.—Assembly of jigged pivot brackets for gamma radiography.

inferior radiographs owing to the relatively large sizes of sources of adequate strength, whilst radon gas sources have the disadvantage of a very short-lived activity, the half-life being only just over three days. The half-life is the period of time in which a radioactive substance decays to half its original strength. According to the physical laws of radioactivity, this half-life is quite independent of source strength and is a characteristic of particular radioactive isotopes.

By the use of radio isotopes, concentrated sources of gamma radiation with reasonable half-life values are obtainable. Even so, the choice is limited, but cobalt 60, for example, a pile product, has a half-life of over five years, and the activity per unit source volume can be made more than ten times that of the best value for radium sources. As more powerful neutron densities become available in newer piles, this factor will be further improved.

Cobalt 60 is, however, not the solution to all radiographic problems in the foundry. Its very penetrating radiation, corresponding roughly to an X-ray tube operating at a peak voltage of 1·8 million volts, makes it very suitable for radiographing steel sections from about 2 in. to 3 in.; but the relative ease with which these rays penetrate less dense metals or thinner sections of steel renders cobalt 60 unsuitable for their radiography. After all, it must be remembered that it is the absorption in the metal which enables us to differentiate between sound and unsound areas. As an example of an isotope emitting softer radiation (corresponding to an X-ray tube peak voltage of about 900 kV.) I would like to mention caesium 137. This is a relatively rare fission production of uranium 235 and has a half-life time of more than 30 years. I hasten to add that this isotope is only in the research stage, but we have good reason to believe that experiments with it will prove successful.

One of the most important advantages arising from the availability of the new sources of gamma rays is an economic one. Until two or three years ago, a foundry wishing to instal suitable apparatus for radiographic examination was faced with the alternative of buying a relatively costly X-ray set or purchasing its own radium, either of which could well result in an expenditure of some thousands of pounds. To-day, it is possible for an outlay of a few hundreds of pounds to use these new radio isotopes. Furthermore, with these relatively inexpensive sources of gamma rays it is possible to penetrate far greater thicknesses of steel, brass or bronze, than could be radiographed with a medium sized X-ray set. As a result of employing these more penetrating radiations, the amount of information obtainable per radiograph has increased considerably; the pivot bracket castings shown in Fig. 1 provide an excellent example. Originally, coverage of these castings using a 400 kV. X-ray set was achieved with 8 shots. To-day, using radio-tantalum, which has rather similar characteristics to radio-cobalt, a more comprehensive examination has been secured with only three views per casting. This is a direct result of the additional penetrating power which enables the numerous section junctions in this casting to be covered fully.

The use of these new isotopes is now providing the foundryman with a rapid and relatively inexpensive method of checking the techniques for new designs of castings before going into full scale production. In many instances they are indicating ways in which old foundry methods can be improved, particularly in respect of obtaining higher yields of steel. A full description has been given by some of my colleagues at Hadfields of the great changes and benefits that have arisen through the introduction of gamma radiography in our own foundry [7 (p. 34 ff).] I should not like to imply, particularly to an institute whose members are specialists in the art of founding, that sound castings capable of giving first-class service have not been made in the past, but rather that the methods which had to be employed to ensure such desirable results were frequently long and expensive, involving as they did, the cutting up and sectioning of pilot castings or the provision of over-sized heads. This new approach enables reliable foundry procedures and methods to be laid down at the start, which will help in securing the regular production of commercially sound castings at a maximum economy in metal usage and production costs.

Fig. 2 is a radiograph of a wheel centre taken obliquely through its rim beneath a head position. This is typical of castings made by original methods. It will be seen that a small shrinkage defect does in fact exist below the head, but castings similar to these have given excellent service for many years. The new technique developed with the help of gamma ray examination was not so

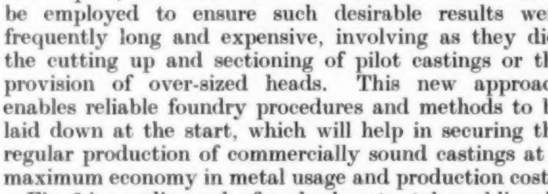


Fig. 2.—Radiograph of wheel-centre (old method).

much concerned in improving the soundness of the casting, but rather with increasing the yield of steel.

Fig. 3 shows a radiograph of the same type of casting as made by present methods. It will be seen, incidentally, that the defect has disappeared, but of considerably greater importance is the fact that the yield has increased by as much as 12%, and experience has shown that fettling costs have also been noticeably lowered. This is not at all an exceptional example, and it is worth noting that we have carried out some 500 similar technique investigations during the past two years. In nearly every instance appreciable savings have been achieved, and I believe that this supports my earlier somewhat sweeping statement that "something approaching a revolution in foundry practice has been achieved by the use of gamma radiography."

I propose to survey briefly further research work which we are now undertaking, having as its object the improvement and further development of the uses of this new technique for the purpose of speeding up the work and reducing the costs. In this connection, tribute should be paid first and foremost to the excellent work which is being carried out by the Radiochemical Centre at Amersham and the Isotope Division of the Atomic Energy Research Establishment at Harwell. We are co-operating closely with these organisations in exploring the radiographic applications of new isotopes such as caesium 137 and cerium 144, because the former will provide good defect-detection sensitivity in thin metal sections, while the latter can penetrate great metal thicknesses.

Some mention must also be made of the relatively new technique of radiological scanning. Here the main objective is to eliminate the use of photographic methods and to give a quick survey of a specimen by traversing it through its thickness with a collimated gamma ray beam, the intensity of which is recorded with the help of Geiger-Muller, proportional or scintillation counters. Fig. 4 shows a scan we have prepared along the axis of the heads of two castings made by different steel processes, the one being basic, the other acid open-hearth steel; both are nominally of the same composition and were cast at the same temperature. In this illustration, the intensity-distance graph can be compared with the shape of the section head, and it will be agreed that the experiment is quite promising, in that the curves would show a foundryman adequately the type of feeding which these two heads of different types of steel have provided.

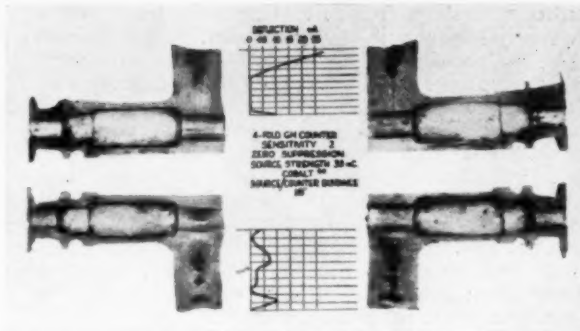


Fig. 4.—Geiger-Muller counter scan of two feeder heads.

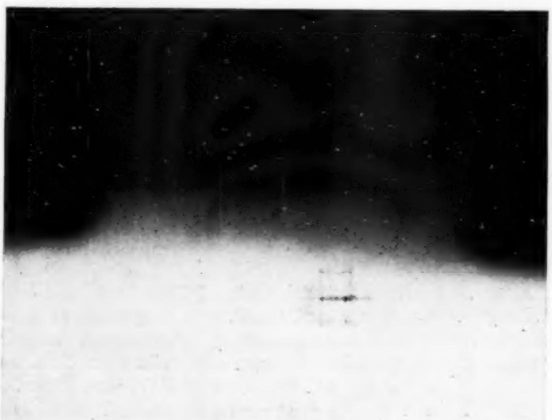


Fig. 3.—Radiograph of wheel-centre (new method).

Gamma radiography, however, is by no means the only benefit that will accrue to non-destructive testing techniques from the advances in nuclear-physical research and technology. The foundryman will watch with much interest developments in the construction of synchrotrons and linear accelerators that will be capable of providing radiation sufficiently penetrating for the examination of metal sections two or three times greater than those which we have been able to handle so far.

We need not, however, look so far into the future for other applications to non-destructive testing. As long ago as 1939 Kaiser[8] drew attention to a novel use of radioactive substances in non-destructive testing. He has described a method of crack detection in which specimens can be dipped in radioactive solutions or coated with greases containing radioactive substances. After removing the solution or grease from the surface of the specimens, sufficient radioactive material is left in the cracks or flaws to enable them to be detected by the use of photographic films. The method is of course very similar to the age-old oil and chalk method, which, like the radiation method, is applicable to non-magnetic as well as magnetic materials.

Tracers

This radioactive method of crack-detection is typical of the tracer methods I am about to discuss. All of them depend on the fact that by virtue of radiation emitted it is possible to trace minute quantities of radioactive isotopes which in their other physical, chemical and metallurgical behaviour resemble elements in their ordinary state. It is thus possible to obtain detailed knowledge on how individual substances behave in complex industrial processes. This tracer method, therefore, conforms closely to one of the outstanding principles of experimental science; the abstraction of the relevant from the irrelevant. When Ohm, to illustrate the argument by a simple example, studied the voltage/current relationship in simple electrical circuits, the precision with which he was able to prove his law was due to the ease with which the circuits could be isolated from external, uncontrolled influences of their environment. Complex industrial processes respond to scientific investigation only in as far as scientists can isolate one

controlled feature from all other influences upon a physical measurement. In tracer studies, it is possible with great sensitivity to observe almost exclusively radiation from one selected type of atom in the system. Therein lies its unique attraction.

Industry in general, and foundries in particular, should realise the versatility and power of this new technique. Burning problems which might be solved by its use abound. How often, to quote one type of such problem, are foundrymen and metallurgists in general involved in disputes relating to impurities in castings, ingots or forgings. Have they been carried over from the melting furnace, picked up from refractories, or are they the result of chemical reaction ?

While my mention of the origin of impurities in steel and in metals generally was chosen to arouse your interest, the self-same example serves to illustrate the limitations, or at any rate the experimental difficulties, of the new technique. For what use is it, say, to introduce radioactive material into the refractory lining of a ladle, unless the physical behaviour of the lining remains the same, unless the radioactive constituent wears away at the same characteristic rate, unless its stability within the molten steel typifies that of the refractory material studied, and unless the operators and the users of the steel are to remain undamaged by the experiment ! It would thus not be proper to discuss such individual applications without first discussing the general considerations underlying tracer studies, and above all issuing a general warning of the medical hazards involved.

The handling of gamma ray sources in radiography necessitates safety precautions which are now fairly well understood. In tracer work, however, every individual experiment must be designed with a view to avoiding not only exposure of personnel to excessive radiation but also ingestion of appreciable quantities of radioactive materials. This is a subject which everyone should study before experimenting with any radioactive materials. Sound advice is available in an introductory manual on the control of health hazards from radioactive materials issued by the Ministry of Supply.[9]

Medical hazards are not, however, the only limitation to the mode of planning of tracer experiments. One must refer first to the detecting—and often measuring—of the activity itself, which depends on the type, energy and intensity of radiation, as well as on the half-life of the nuclide chosen—usually from all too few alternatives.* In addition, the physical or chemical behaviour of the radioactive material must often be experimentally typical of the material whose course is being " traced " through some more or less complicated physical, chemical, metallurgical or biological system. The radioactivity itself must not, furthermore, significantly alter the characteristics of the system. Ideally, the radioactive material must in some experiments admix itself evenly over part of the system and in others it must be drawn exclusively to special chemical or physical sites.

These points are best explained by examples † classified into the three types of tracer experiments :—

(1) Physical Indicators

In this class, the course of materials is followed through systems without, however, entailing chemical interaction. The chemical nature of the tracer need not always be identical with the traced substance. A bee-keeper—to start with an almost trivial example—who labels his queen bees with radioactive material for ease of locating must be sure that the source is of such size and radioactive power, and is so affixed that it will neither disturb the queen in her work nor influence appreciably her inheritance characteristics by gene mutations. Yet the radioactivity must be sufficiently potent and lasting to enable the queen to be rapidly and accurately located.

The method of crack-detection in metals by radioactive materials discussed in an earlier section is another instance of tracer work in this class. If the radioactive material is to indicate the cracks, it must on the one hand, be efficiently removed from all surface features other than cracks, and it must, on the other hand, be sure to enter cracks if present. Furthermore, the solution or suspension used must not be corrosive to the metal.

Precisely similar planning is used for locating leakages in pipes or cables, for following the descent of the ball in the falling-ball viscometer, for finding liquid levels in high-pressure vessels, or possibly even furnaces, and for many other applications.

Even when the aim of the experiment is more complicated than merely the location of the traced material, the procedure may be simple. When, for example, Voice [7 (p. 53)] wished to study the rate of refractory attack in blast furnaces, it was perfectly satisfactory to use radio-cobalt, a cheap and convenient gamma emitter, in pellets embedded at different points and depths. The stated conditions only require that the cobalt shall remain in place as long as the surrounding refractory is intact, and that this surrounding refractory should be typical and unaffected by the radioactive material. The radioactivity, where it can be observed from outside, falls virtually to nothing as soon as the liquid metal penetrates to the location, and in consequence, the iron itself will then show a sudden, measurable increase in activity.

Air ventilation tests in confined spaces is another example of the uses of physical indicators [7 (pp. 4 and 12)]. The planning of such experiments is not easy when vapours are used. Even radioactive isotopes of the inert gases will not behave exactly like ordinary air. After release of the radioactive vapour or gas, the experimenter must know to what extent he is justified in considering it evenly admixed with the air throughout the volume under investigation, and if the egress of the radioactive constituent typifies that of air.

In some of the seemingly simple applications for physical tracers, it is almost impossible to satisfy the conditions that have been discussed. When trying to trace dust, one is in great danger of testing merely the progress of the radioactive dust added artificially without this typifying the prevailing dust. This is one of the chief reasons why the problem of silicosis does not readily yield to tracer methods. It is indeed quite a triumph that experimenters in this field are obtaining data of limited but proved significance by the use of radiotantalum.[13]

Another group of experiments in this class deals with difficult determinations of liquid volumes, be it of blood in a body, water in a lake, or steel in a furnace. Experimental significance is achieved only if the radioactive material is not absorbed by the containing walls and is evenly divided in the volume of the liquid. Salt, for example, may dissolve quickly and evenly in a glass of water, but as soon as the dimensions of the volume

* As introduction to this subject the reader is referred to general textbooks such as ref. 10.

† Wyatt gives an excellent general survey of the application of tracers (ref. 11)

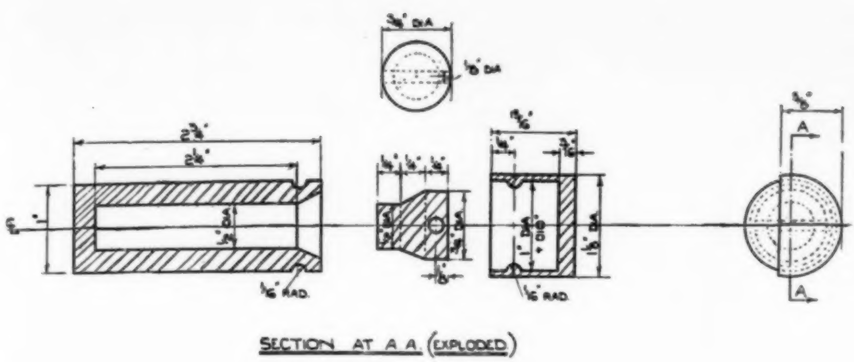


Fig. 5.—Carbon 14 diffusion capsule.

studied become large compared with linear diffusion rates, even mixing cannot be assumed to have occurred even after some time lapse.

(2) Indicators of Chemical Traces

In this class of experiments, use is made of the astonishing sensitivity with which radioactive isotopes can be detected. Exact figures depend to a tremendous extent on the elements concerned and the material in which they are to be detected. A chemist will not, in general, feel insulted if you tell him he can detect concentrations of elements under favourable conditions to one part in a million ; but you run some risk of insulting a nuclear physicist by saying that he can detect elements at no less than a millionth of the concentration needed by the chemist. That statement is remarkable enough and in consequence you will appreciate that a new field has been opened to the chemist particularly. It is necessary only to add a radioactive isotope in concentrations of one per million and to allow it to attain equilibrium with the corresponding inactive element in a system in order to be able to detect its presence after dilution to one part per thousand million.

Applications of this class of tracer experiment are numerous and varied, but one example suggests itself for mention in this lecture, for the steelmaker has not been slow in using this technique for his problems.[14] All theories of desulphurisation of iron by slags are based on the idea that the sulphur finally becomes fixed in the slag as sulphide of calcium or sodium ; but how this is brought about is not fully understood. One question is : could the sulphide be formed by reaction inside the metal ? As this would involve calcium entering the metal, detection of that element in the bulk metal would afford a clue. Chemical or spectrographic estimations are insufficiently delicate to detect its presence at concentrations less than about one part in ten thousand.

Small melts of iron at about 1,600° C. were, therefore, made in a graphite crucible under slags in which a portion of the lime content contained radioactive calcium. Philbrook and his collaborators failed to detect the presence of any calcium in the metal, at any rate to an amount of more than 0·6 parts per million which was the approximate, and perhaps not very impressive sensitivity achieved. From this, the experimenters concluded that the sulphide reaction had not occurred to any significant extent.

Attention is drawn to a specific feature of the radioactive method of determining chemical traces, which is well illustrated by the previous example. Conventional chemical methods are limited in accuracy attainable because the bulk metal must be dissolved in reagents which themselves are inevitably contaminated with traces of calcium. It is true the chemist manages to eliminate part of the error so introduced by blank analyses, but how much more fortunate is the nuclear physicist who does not care how serious is the contamination with inactive calcium.

(3) Chemical Indicators

Radioactive isotopes in this type of investigation are used to trace the course and locate chemical elements, radicals or compounds throughout systems in which chemical reactions occur. For the purpose of this discussion, metallurgical alloying may be regarded as a chemical reaction.

In this field many striking experiments on auto-diffusion in metals have been reported.[15] Auto-diffusion is the process by which metal atoms move through a matrix of chemically identical atoms. It can be studied only by tracer techniques. Radioactive isotope material is placed on, or sandwiched between, layers of inactive metal by rolling, pressing or electro-plating. The depth of penetration of the active into the inactive material is measured after known periods of time under carefully controlled physical conditions. Diffusion has been shown to proceed fastest along the grain boundaries owing to the atomic disorder which, however, is directly influenced by radioactivity itself. It is not surprising, therefore, that some experiments in which the radioactivity is induced on one side of the specimen by neutron bombardment have been shown to be subject to an appreciable experimental error.

The results of these experiments may not directly affect the foundryman, but they give new data for just the sort of theoretical considerations as are needed for progress in knowledge on metals and alloys. Who can doubt that ultimately every foundry will benefit from such advances.

To return, however, to more immediately useful applications of tracers : in the steel industry the problems of "tracing" steel through casting, heat treatment and other processes may arise. The question, for instance, where does the liquid steel go to that is poured into the tops of heads of castings and ingots, if it could be answered, would help to solve many problems of practical importance.

It is instructive to cast our minds back to the days when Sir Robert Hadfield grappled with the self-same problem with the less powerful scientific tools which were then at his command. I refer you to the colour

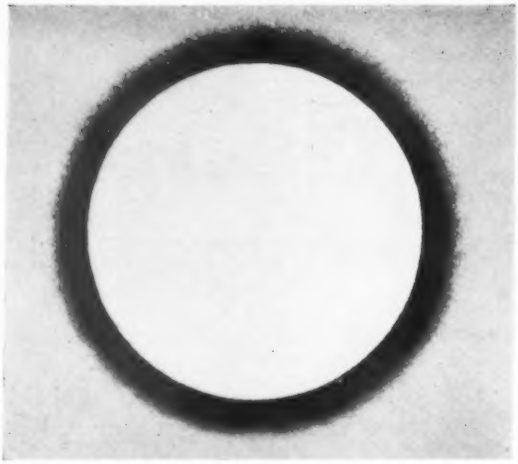


Fig. 6. — Autoradiograph of section through carburised steel container.

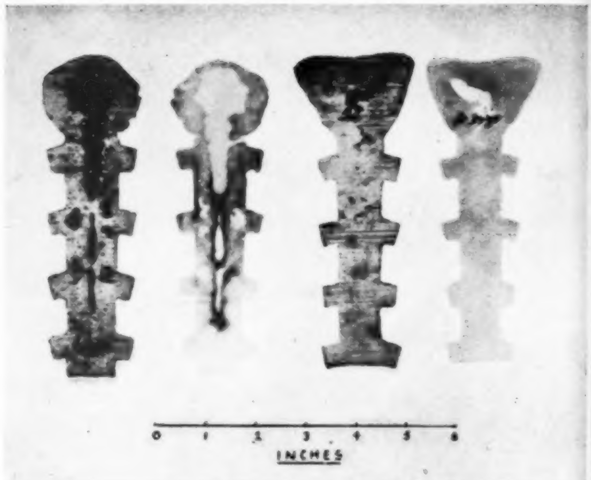


Fig. 7.—Autoradiograph of radioactive castings.

prints published by the Iron and Steel Institute in 1912[16] showing sections of ingots whose heads were topped up with molten copper. Sir Robert was well aware that the fluidity, the density and the other properties of copper differed too much from those of steel to place the results beyond suspicion ; but what else could he have done in those days ? Besides, his results were successful, for they did indicate strongly that feed metal penetrated deeply into ingots.

We are repeating these and similar experiments now we can make small additions of radioactive elements to steel. Partly because other investigators are already experimenting with radioactive iron and cobalt in steel, and partly because of the inherent advantages of radiocarbon—that is its long half-life and the purity and shortness of range of its radioactive emanations—the author has chosen the seemingly more difficult course of using radioactive carbon and employing a modification of a technique originated by Stanley.[17] In the mild steel capsule (Fig. 5) used by the author, a radioactive carburising charge consisting of barium carbonate containing carbon 14 and inactive graphite is sealed. Heat treatment follows for 6 hours at 900° C. in an atmosphere of nitrogen. The extent of carburisation achieved is shown on the auto-radiograph after sectioning the container perpendicularly to the cylinder axis (Fig. 6). This auto-radiograph also illustrates the decrease of the case-hardening effect with increasing distance from the inner cylinder surface.

The radioactive steel so obtained can be re-melted and run into the heads of castings, which are subsequently sectioned for preparation of auto-radiographs. The results already obtained (Fig. 7) prove not only that carbon segregation can be shown up strikingly by this method, but also that the head metal feeds deeply into the body of the casting as Sir Robert Hadfield and some later investigators suspected.

Nuclear Energy

During the last few years, many serious warnings have been issued by scientists all over the world that not only are we wasting our present fuel resources, but also that, even with the exercise of great economies, the coal and oil resources of our globe are likely to be exhausted in the next hundred years. Fortunately, the advances that are now being made both in the United Kingdom and the United States are such that it is believed that nuclear fuel will be able to replace coal and oil as a means of power production within such a period of time.

A recent report of the Material Policy Committee of the U.S.A.[18] has provided some intriguing estimates of the possibilities. Table I shows some of the more outstanding statistics.

When we consider that the present needs of this country could be met by 10–15 tons of uranium a year, the importance of nuclear energy is brought home forcefully to us as large consumers of electrical energy in the metallurgical industries.

Sir John Cockcroft[19] in a lecture given to the Institution of Electrical Engineers in January of this year on the subject of "Nuclear Reactors and their Applications" has provided the most up-to-date picture of progress in this field. He discussed in some detail reactors for power production and explained that in the next stage of development it would be possible to use normal natural-uranium power reactors rather similar to those already in operation at Harwell and Chalk River. By use of a pressurised external envelope, either gas or water could be employed to absorb the heat from the reactor, and by means of a heat-exchange system steam could be produced and used in the conventional power station turbines. The fuel elements would have to operate at 350°/450° C. to ensure reasonable thermodynamic efficiency. The size of such a unit would be comparable with that of the present British Electricity Authority set.

TABLE I.—WORLD FUEL RESOURCES.
(1 Unit = 10^{18} B.Th.U.)

Present annual world consumption of fuel	=	0.2 units
World reserves of coal	=	33.0 units
World reserves of oil	=	5.6 units
(a) Supplies of uranium available at a cost of \$100/lb.	=	25,000,000 tons
If (a) 100% utilised	=	1,700 units
(b) Supplies of uranium available at a cost of \$50/lb.	=	3,700,000 tons
If (b) 100% utilised	=	250 units

Ultimately, the aim must be to " burn " all or at least a very high percentage of the nuclear fuel, i.e. the uranium 238 as well as the 235. Eventually this would be achieved by the use of fast-fission reactors in which graphite or heavy water, which are used for reducing neutron velocities to thermal speeds, would not be required; instead a core consisting of fuel elements of relatively pure fissile material such as uranium 235 or plutonium would be used. The heat developed by burning this material would be removed by use of a suitable liquid—in the first experimental unit in the U.S.A. a sodium-potassium alloy of low melting point has been used. In a heat-exchanger the liquid metal would then provide the power to drive a turbine.

Surrounding this core would be a blanket of natural uranium or thorium in which the surplus escaping neutrons would be caught and further supplies of the fissile plutonium formed by conversion of the uranium 238. Periodically both the fuel elements in the core and the uranium in the outer blanket would have to be taken out for chemical processing. Plutonium would be extracted from the blanket; this could then be used for making up new cores. The old core would be regenerated by removing fission products and adding some primary fuel.

Convey,[20] in a recent paper to the Canadian Institute of Mining and Metallurgy, has covered rather similar ground. In addition, he has given some interesting figures relating to present-day estimates of the cost of power-producing reactors which show a great reduction on earlier and more pessimistic estimates. For example, it is now thought that a small reactor capable of producing useful power for an undeveloped area could be built for approximately £2,000,000.

It will be seen that there are many very difficult metallurgical and engineering problems to be solved before the final large-scale power producing unit is evolved. Some of these difficulties will now be considered.

Materials for the Atomic Pile

Whilst the next part of this lecture will probably be of more interest to the metallurgist than the foundryman, it may well be that the latter may in the foreseeable future be asked to cast shapes in some of the newer metals and alloys that up to now have been looked upon as metallurgical rarities. So far, one of the most important considerations in choosing an alloy for a particular purpose has been that of ease of casting. The foundryman of the future may well find himself in the position of being asked to cast alloys that are not of his own selection, and which will involve the development of new techniques to obtain the required soundness.

Nuclear energy plants whether they be primary graphite or heavy-water piles for the production of plutonium, or whether they be reactors designed to produce energy from the burning of nuclear fuel, present a number of novel problems to the metallurgist, the designer and the manufacturer. In conventional power stations or chemical engineering plants the failure of a blade or the cracking of a weld may cause a temporary shut-down, but in a plant burning or processing radioactive materials the consequences are infinitely more serious since the intense radioactivity makes maintenance, as ordinarily understood by the engineer, virtually impossible. The standards of soundness and reliability, and the inspection requirements are, in consequence, much more rigid. These aspects have been dealt with by Sir Christopher Hinton[21] in his recent May lecture to the Institute of Metals.

In atomic piles everything depends on ensuring that the best use is made of the neutrons which sustain the chain reaction; these must not be wasted in capture by foreign atoms in the materials of construction. Certain elements such as boron and some of the rare earth metals have a strong capacity for capturing neutrons, whereas light metals such as beryllium, magnesium, zirconium and aluminium are relatively transparent to neutrons; this latter group is thus particularly attractive for materials for sheathing the nuclear fuel elements. Similar considerations apply to the uranium rods and the graphite moderator when it is necessary to ensure that poisoning elements such as boron, cadmium and some of the rare earth elements are present only to the extent of a few parts per million. Yet these elements have their uses as control rods or shields where neutron capture is essential for keeping the chain reaction under control or for preventing damaging radiation from escaping to the atmosphere.

Nature certainly provides us with some strange partners. A good example is zirconium, a metal that is becoming increasingly important because of its very low capacity for capturing neutrons. Associated in nature with zirconium is found hafnium, which has a very high capacity for absorbing neutrons. Complete, or nearly complete, chemical separation of the two is not easy. Whilst boron or cadmium are normally used in control rods to-day, the use of hafnium or one of its alloys for the same purpose in the future is a real possibility.

A number of important papers on materials of construction for atomic plants have been published during the past year. The summary provided by Burke[22] when discussing the problems facing the metallurgist in the selection of materials for reactor cores provides a comprehensive picture of the various factors involved. His list is as follows:—

(*a*) Corrosion and erosion problems.
(*b*) Thermal stresses and fatigue.
(*c*) Diffusion between nuclear fuel and its protective cladding (the so-called " can ").
(*d*) Radiation effects.
(*e*) Changes in composition as a result of fission.
(*f*) Recovery and chemical processing of the nuclear fuel.

To these he might well have added: the choice of material for the initial extraction and purification plants used in the production of high purity uranium. Here traces of impurities which are not permissible in the final product may arise as a result of corrosion, or even of the use of chemicals below the required standard of purity.

The intense neutron bombardment to which materials may be subjected in the heart of a reactor can actually alter atomic arrangement and bring about changes in mechanical and physical properties. Billington[23] has indicated that annealed metals may increase in hardness, an ordered arrangement of atoms as in a gold copper alloy may become disordered, and even transformation can occur from one metal to another element. For example, copper can be transformed to zinc by collision and neutron capture.

Hafstad,[24] when addressing the Conference held in New York last October to discuss " Atomic Energy in

Industry," made reference to the special difficulties that are being encountered in transferring heat from the reactor to the conventional type of power-producing plant. He explained the peculiar advantages to be obtained from the use of liquid metals in this connection. Promising results are being obtained with sodium and sodium/potassium alloys as heat transfer fluids. He warned his audience of difficulties that arose in handling these metallic fluids at red heat; possibly we may guess that they may be due to stress-corrosion effects accentuated by the inevitable sharp temperature differences that are encountered between fissile material in the core and the outer sheath. It is clear that, for reasons of economy, the future trend will be towards higher temperature operation which will bring with it new and as yet unstated problems.

Conclusion

It has not been possible in the brief time at my disposal to do more than draw your attention to some of the more outstanding applications of the new radioactive elements, and at the same time touch briefly on possible future developments in the use of nuclear energy for the production of power.* I hope, however, my lecture may have stimulated some of you to think of new ways and means in which these modern tools will help you to bring your varied processes under closer scientific control with consequent benefit to the quality of your products. You will have realised from the closing sections of my lecture that I am a firm believer in the future possibilities of nuclear energy as an economic source of power production. Coal resources are drying up, and whilst wind, sun and water will continue to make useful contributions, something must be found to take the place of oil and coal. I believe nuclear energy will do this for us. Thus I close on the note on which I started in expressing my lively faith that the good that will arise from these new scientific developments will far outweigh the evils that could arise if they were used for purposes of destruction.

The author wishes to acknowledge the help that he has received from many of his colleagues at Hadfields in the preparation of this lecture. In particular his best thanks are due to Dr. S. A. Main and Mr. H. S. Peiser for a careful survey of the literature and help in the preparation of the manuscript.

* The economic and social implications of these developments are discussed in a recent American book (Ref. 25.).

REFERENCES.

1 "A general Account of the Development of Methods of using Atomic Energy for Military Purposes under the Auspices of the United States Government, 1940–1945." Smyth, H. D. Reprinted by H.M.S.O., 1945 (2/6d. net).
2 Akers, Sir Wallace, "Metallurgical Problems involved in the Generation of useful Power from Atomic Energy." *Journal Institute of Metals*, **75**, (11), 1947, 667–680.
3 Cockcroft, Sir John D., "The Possibilities of Nuclear Energy for Heat and Power Production." *Proceedings, Institution of Mechanical Engineers*, **156**, (2), 1947, 206–211.
4 Colbeck, E. W., "The Metallurgy of Uranium." *Metal Industry*, **81**, (19), Nov. 7th, 1952, 361–363; and (20), Nov. 14th, 1952, 387–389.
5 Finniston, H. M., "The Metal Uranium. A Survey of its Extra-Nuclear Properties." *The Times Science Review*, (6), Winter, 1952, 11.
6 Hadfield, Sir R. A., Main, S. A., and Brookebank, J. (a) "X-ray Examination as applied to the Metallurgy of Steel"; (b) "Testing the Absorption Power of Different Steels under the X-rays." *Trans. Par. Soc.*, **15**, February, 1920.
7 "Radioisotope Techniques." H.M. Stationery Office, London, 1952, p. 55 ff.
8 Kaiser, H. P., "Possible Uses of Radioactive Substances in the Testing of Metals." *Trans. A.S.M.*, **27**, 1939, 403.
9 "Introductory Manual on the Control of Health Hazards from Radioactive Materials." Prepared for the Medical Research Council by the Ministry of Supply, Atomic Energy Research Establishment.
10 Pollard, E. C., and Davidson, W. L., "Applied Nuclear Physics." John Wiley & Sons, Chapman & Hall, 1951.
11 Wyatt, L. M., "Metallurgical and Analytical Uses of Radioactive Tracers." Proc. Sixth Chemists' Conference, B.I.S.R.A., 1952, 44.
12 Seligmen, H., "Production and Uses of Radio-isotopes." *Nature*, **171**, 1953, 588.
13 Nagelschmidt, G., Private Communication.
14 Philbrook, W. O., Goldman, K. M., and Helsel, M. N., "Radio-calcium to Study the Distribution of Calcium between Molten Slags and Iron saturated with Carbon." *Trans. A.I.M.S.*, **188**, 1950, 361.
15 Eastwood, W. S., Marley, W. O., Finniston, H. M., and Williams, A. E., "Radioactive Tracers in Metallurgical Research." H.M. Stationery Office, 1950.
16 Hadfield, Sir Robert, "On a New Method of Revealing Segregation in Steel Ingots." *Journal Iron and Steel Institute*, **66**, 1912, 40.
17 Stanley, J. M., "A Carburising Experiment with Radioactive Carbon." *Metal Progress*, **52**, 1947, 227.
18 "Resources for Freedom." Vols. 1 to 5. Being the Report of the President's Materials Policy Commission. June, 1952, U.S. Government Printing Office, Washington D.C.
19 Cockcroft, Sir John, "Nuclear Reactors and their Applications." Institution of Electrical Engineers, 1953. (*Nature*, **171**, March 7th, 1953, 411).
20 Convey, J., "Uranium as a Source of Energy." *Canadian Mining and Metallurgical Bulletin No.* 491, March, 1953, 124-127.
21 Hinton, Sir Christopher, "The Present and Future Metallurgical Requirements of the Chemical Engineer." Annual May Lecture to the Institute of Metals, London, 1953.
22 Burke, J. E., "Metallurgical Problems in Atomic Energy." A.S.M. Regional Meeting, Oak Ridge, Sept. 18th–19th, 1952, *Metals Review*, December, 1952, 9.
23 Billington, D. S., "The Effect of Nuclear Reactor Radiation on the Properties of Metals." A.S.M. Regional Meeting, Oak Ridge, Sept. 18th–19th, 1952, *Metals Review*, December, 1952, 9.
24 Hafstad, L. R., "Atomic Energy in Industry." Conference, New York, mid-October, 1952, *Metal Progress*, December, 1952, 138–142.
25 Isard, W., and Whitney, V., "Atomic Power." George Allen & Unwin, Ltd., 1952.

Institute of British Foundrymen

continued from page 32

MOULD REACTION IN ALUMINIUM-ALLOY CASTINGS

By Marjorie Whitaker, B.Sc., A.I.M.

This paper is an account of experimental foundrywork, mainly on 90/10 aluminium/magnesium alloy, carried out in the laboratories of the British Non-Ferrous Metals Research Association during the past ten years. Investigations have shown that, when cast in green-sand moulds, aluminium alloys containing magnesium react with the moisture in the mould. The reaction increases with increasing magnesium content and with the time taken by the casting to solidify. It is, therefore, greatest in heavy sections of alloys with high magnesium content. The reaction may result in severe and often deep oxidation of the surface of the casting, and absorption of hydrogen. The hydrogen thus absorbed is liberated within the casting during solidification, causing porosity. Measurement of the distribution of gas porosity resulting from the reaction showed that it was concentrated beneath the surface and decreased rapidly towards the interior. The reaction was not prevented by drying the mould, nor did the addition of various corebinders have any effect on it. From examination of the influence of minor constituents in the metal, it was found that additions of beryllium largely inhibited this reaction 0·004% addition of this element being most effective within the composition range 0·0001–0·1%. This addition by itself was found adequate for thin sections up to 1 in. diameter, or about ½ in. plate thickness, provided contamination with sodium was avoided, but, for thicker sections, taking longer to solidify, an inhibitor in the moulding sand is also necessary. By adding boric acid or ammonium bifluoride to the sand, sections up to 4 in. diameter or 2 in. plate thickness can be made sufficiently free from mould-reaction for most practical purposes. Experiments showed that the loss of beryllium on remelting the alloy containing 0·004% was small, and it was confirmed that beryllium does not coarsen the grain. Special moulding sands containing boric acid or sulphur have harmful effects on certain alloys for which they are not intended, and the author includes a few observations on this subject.


HANNA

NEWS AND ANNOUNCEMENTS

National Foundry College

THE National Foundry College receives nominees of firms engaged in the foundry industry (cast iron, malleable cast iron, steel, non-ferrous), for a diploma course of some 10 months' duration starting each year in September. For those not fully prepared, there is a preliminary course of six months' duration, also starting in September. Hostel accommodation is available in each case. The College anticipates that students entering for either course opening in September, 1953, will be able to make use of the new buildings of the College at Wolverhampton (at any rate, of the lecture rooms and some laboratories) although the formal opening date is yet to be announced. This provision will enable a larger number of students to be accommodated, and the industry is earnestly invited to consider what nominations can be made for the next session. Full information can be obtained from the Head of the College, Mr. J. Bamford, B.Sc., National Foundry College, Wulfruna Street, Wolverhampton.

English Electric Transformers for U.S.A.

AN order has been received by English Electric Export and Trading Co., Ltd., from the United States Army Corps of Engineers for ten transformers for the Chief Joseph Dam. They are 103,300 kVA continuously-rated, single-phase, outdoor-type power transformers for connecting in three 310,000 kVA three-phase banks, ratio 230 kV/13·2 kV. (One transformer is a spare). The 230 kV winding is designed for star connection (neutral grounded) in the three-phase banks. Each transformer will have an externally-operated off-circuit tap changer on the high voltage winding. They will be forced oil cooled, the oil being cooled by water through a heat exchanger.

C.D.A. Technical Survey

A Valuable New Service

THE Copper Development Association has for some years prepared and issued to its members, twice a year, a review of recent technical developments in the production, properties and application of copper and its alloys, with a comprehensive bibliography. It is believed that these reviews should be available to a wider public, and they are now being published in January and July each year, under the title "Technical Survey." A copy will be sent free of charge upon request to anyone who is interested. It is important that those who wish to take advantage of this valuable new C.D.A. service should write to the Association at Kendals Hall, Radlett, Herts., asking for their names to be placed on the mailing list.

New Five-Year Plan for Hungary

HUNGARY's steel production is to be raised from 2,200,000 tons to 3,500,000 or 4,000,000 tons annually during the second Five-Year Plan due to start in January, 1955. At the same time, coal production will be raised from 27,500,000 tons to 40 or 50,000,000 tons and electric power from 6,050 million kilowatt hours to 10 or 12,000 million. A large hydro-electric station will be constructed on the Danube and the area of irrigated land will be increased to 741,320,000 acres. In addition 250,000 new dwellings will be constructed.

Aluminium Recovery from Clay

A CONTINUOUS electrolytic process for producing high-purity alumina from low-grade domestic ores is ready to be licensed, after being proved with more than a year's operation in a pilot plant in Europe. The process, which is continuous and recovers 99–100% of all reagents used, has been operating purposely with low-grade kaolin clay (10% alumina and 80% silica) to prove that there is practically no limitation on the impurities it can handle.

Preliminary cost estimates for the Lobeth process indicate that 99·9% alumina can be produced at 15–20% less than from bauxite with the Bayer process. These costs are based on actual pilot plant work tests, and are converted to U.S. dollars: electrical requirements are less than 2 kWh per pound. The process is licensed through Lambeth Corporation, 624, South Michigan Avenue, Chicago, 5, Illinois, U.S.A.

Honeywell-Brown Sheffield Office

HONEYWELL-BROWN, LTD. have established a new branch office in Sheffield, which will be the headquarters for sales and service personnel dealing with the company's range of industrial instruments, serving customers in Lancashire, Yorkshire and the North Midlands. The facilities provided by this Sheffield office, together with those of London and Glasgow and the Birmingham office opened earlier in the year, will enable the company to place its resources and experience more readily at the disposal of its established and potential clients. The address of the new office is:—20, Oak Dale Road, Nether Edge, Sheffield, 7. (Telephone: Sheffield 53093).

Babcock & Wilcox in Japan

FURTHER to previous reports of the formation of a new Joint Company in Japan taking the place of Toyo Babcock K.K., the new Company, Babcock Hitachi Kabushiki Kaisha, has been established with the following address: Tokiwabashi Office, 52-Chome, Ote-machi, Chiyoda-ku, Tokyo.

Industrial Partnership

THE VACUUM OIL CO., LTD. and Charrington Gardner Locket (London), Ltd., announce a joint arrangement whereby Charringtons undertake the inland marketing of fuel oils which are now being produced at the Vacuum Oil Company's new refinery at Coryton, Essex. As is well known, the Vacuum Oil Co., Ltd., have been manufacturers and marketers in the United Kingdom of the highest quality lubricants since 1885, and have now entered the automotive and industrial fuel oils market. Charringtons have for over two centuries been engaged in the distributive coal and shipping business,

and have accumulated a wealth of experience in combustion problems. This experience, with the support of a highly qualified technical staff, will also now be available to oil consumers. As a result of this arrangement, a new road tanker fleet will soon be seen in service in the well-known black and gold colours of Charringtons' fleet, with the addition of the now familiar Flying Red Horse trade mark of the Vacuum Oil Company Limited.

The Nickel Bulletin

THE Nickel Bulletin for May contains a data sheet giving the magnetic properties of the nickel-iron alloys, and two of the abstracts report laboratory research on magnetostriction in alloys of the Permalloy type. Other abstracts are of interest to electroplaters, including two dealing with the electrodeposition of tin-nickel coatings, and one describing a laboratory investigation of a method in commercial use for plating on aluminium. Abstracts of American literature include a report on determination of boric acid in nickel-plating baths. Abstracts dealing with alloy steels include a review of the literature of temper-brittleness and a report of research on the effect of composition and heat-treatment on susceptibility to embrittlement.

A progress report comprising a series of papers tracing the history of gas turbine development, reviewing current applications in various fields and emphasising the contribution made by improved high-temperature materials is also included. Other abstracts relating to high-temperature engineering deal with nickel-chromium-aluminium alloys and the properties of titanium-carbide-base materials containing nickel and other metals as binders. Abstracts dealing with corrosion-resistant steels include a survey of stainless and heat-resistant steels in Russia, a report on commercial experience in sodium-hydride descaling of stainless steel tubes, and recommendations with regard to the niobium content of austenitic welding electrodes.

The Nickel Bulletin is published by The Mond Nickel Co., Ltd., Sunderland House, Curzon Street, London, W.1.

Revised British Standard

SOLID DRAWN COPPER AND COPPER ALLOY TUBES. (B.S.378:1953). PRICE 2s. 6D.

THE British Standards Institution has just published a revised edition of B.S.378, which supersedes the 1941 edition, which covered solid drawn 70/30 brass and 70/29/1 brass tubes. The present revision includes in addition to these alloys, tubes in copper, aluminium brass, copper-nickel and aluminium bronze (7% aluminium). The requirements for tubes for screwed glands, and screwed glands for condensers included in the earlier edition have, however, been omitted, and will form the subject of a separate standard.

Copies of this standard may be obtained from the British Standards Institution, Sales Branch, 24, Victoria Street, London, S.W.1.

Hydro-Cyclonic Ore Washing

HUNGARY is said to be saving millions a year by a hydro-cyclonic ore-washing technique devised by Gusztáv Tarján, the engineer who got a 1953 Kossuth award of £600 for his invention.

Tarján's hydro-cyclone is a long cylindrical vessel about 8 in. in diameter, with a tapered bottom. The ore, reduced to a sludge, is pumped under high pressure at an angle into the upper portion of the cylinder. The pressure causes the sludge to rotate and centrifugal force flings the minute manganese particles against the wall, down which they slide by their own weight in a spiral to the bottom of the cyclone. At the same time, other substances of a lower specific gravity, leave the vessel by an upper opening. It is claimed an extraction rate of 75–80% is obtained by this method—against 60% by other methods.

The new hydro-cyclone is applicable to the washing of other ores because of its ability to separate constituents according to their specific gravity.

Personal News

H.R.H. THE DUKE OF EDINBURGH has been pleased to accept Honorary Fellowship of the Institute of Welding.

MR. A. R. DRIESSEN, O.B.E., Commercial Manager of The Indian Cable Co., Ltd., has been appointed Chairman and Managing Director with effect from May 1st, 1953, in succession to MR. D. J. MCINTOSH who has retired.

MR. STEPHEN BAKER, has been appointed Service Manager of Davy and United Engineering Co., Ltd., Mr. Baker received his engineering training at Cambridge University. On his return from service with the Royal Navy, he was for some time Maintenance Engineer at John Baker and Bessemer, Ltd., and joined Davy and United in 1951. The Service Manager's main responsibility will be to develop the organisation for spares sales and service to the customers of Davy and United.

MR. J. J. FRASER, Managing Director of Honeywell-Brown, Ltd., has announced the appointment to the Board of that Company of MR. V. D. MACLACHLAN and MR. L. R. PRICE. Additionally, Mr. MacLachlan has been appointed General Manager of the Company.

THE award of the Institute of Fuel Students' Medal and Prize for 1952 has been made to MR. B. H. HOLLAND, of the Department of Coal Gas and Fuel Industries with Metallurgy, University of Leeds, for a paper on "The Structure and Stability of Flat Burner Flames."

THE Council of the West of Scotland Iron and Steel Institute has awarded Riley Medals to MR. R. P. TOWNDROW, for his paper "Blast Furnace Operation at High Top Pressure," read before the Institute in 1950-51, and to MR. R. BOWMAN, for his paper "Some Practical Notes on Casting of Ingots for Seamless Tubemaking," read during 1952-53.

MR. J. R. GORDON has been elected Vice-President and General Manager of Canadian operations of The International Nickel Company of Canada, Ltd., succeeding the late Mr. R. L. Beattie in both capacities.

MR. LESLIE GAMAGE has been re-elected President of the Institute of Export, for the 11th time in succession.

MR. R. F. LOCKYER has been appointed Sales Manager for the Ainsbury Group, covering the Midlands and Southern England. A well-known foundry executive, Mr. Lockyer was Factory Manager for Magnal Products, Ltd., of Bristol previous to his present appointment.

MR. A. F. C. GARDNER, of Gibbons Brothers, Ltd., has been appointed Northern General Manager and will conduct the business of the Company from their North Eastern Office, at "Cranbourne," Eaglescliffe, Nr. Stockton-on-Tees, Co. Durham.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

Automatic Shell Moulder

THE Autoclino Shell Moulder has been designed to meet all the requirements of modern foundry practice. It is ideal for mass-production work, but is equally of value in the jobbing foundry where the need is for a machine which can be quickly turned over from one pattern plate to another and have all the necessary adjustments made with the minimum of time and effort.

After a preliminary run with the pattern plate to ascertain the length of the various time cycles involved, the timing devices are set to reproduce this cycle. The whole operation is thus correctly timed and fully automatic for the production of each shell mould, and as soon as one has been removed from the pattern plate the cycle is recommenced by pressing the starting button. There are four independent time switches which actuate solenoid-operated pilot air valves, which in turn control the air at both ends of the air cylinders operating the machine. Air at 100 lb./sq. in. pressure can be supplied by a small motor driven compressor and receiver, or connections can be provided for existing air lines where available.

The general process of operation is as follows :—

1. The pattern plate is loaded. This plate is mounted on two dowelled studs, and clamped with two hexagon nuts ; it can accommodate both top and bottom moulds made on the ordinary 16 × 14 in. pattern plate, or a half mould 16 × 28 in.
2. The heating hood swings over the pattern plate and applies infra-red heat for a predetermined period.
3. The hood swings back and the pattern plate is reversed ready to meet the dump box containing the sand/resin mixture.
4. The dump box rises to meet the pattern plate.
5. Dump box and pattern plate are turned completely over to enable the sand/resin mixture to invest the pattern. After a set period, this movement is reversed to allow surplus mixture to fall back in the box which is then lowered away from the plate. The pattern and its investment now turns over to its original position and the heater hood swings over it for the final cure. After a set time the hood returns to its stand.
6. The dump box is lifted up to the ejector plate which engages with the ejector pins and so raises the shell mould approximately 2 in. and holds it off the plate for any predetermined time, during which the shell is removed by the operator. The dump box is then lowered again.

The mechanism is timed by means of a master timer at three-second intervals for each of the air cylinder operations. When it is required to vary the time cycle as in the case of heating the pattern plate, investing the pattern, etc., the master timer cuts out and an independent hand-setting time switch comes into operation. This means that where a variable time setting is essential, an independent clock, which can be hand-set to seconds, automatically comes into action. There are four of these clocks, which are set for the following purposes :—(a) Heating of the pattern plate between each operation ; (b) Investing the pattern ; (c) Curing the shell ; and (d) Holding up the mould on the ejection pins so that the operator can remove the shell.

The time of the complete cycle will vary with different pattern plates, according to the thickness of the mould required, but an average cycle may be taken as 2½-3 minutes.

Clino Foundry Supplies, Ltd., London.

Autoclino Shell Moulder. Left—in normal working condition ; right—with guards removed.

Copper-Aluminium Heat Exchanger Tube Alloy

NARGLAS " B " is an alloy designed to withstand the scaling produced in gas turbine atmospheres at temperatures in the range 0–600° C., and the stresses, probably not greater than 1 ton/sq. in., produced by the difference in pressure between the exhaust gases on the outside and the preheating air on the inside of the tubes. The material has to withstand corrosion in an atmosphere generally containing up to 0·10% sulphur as SO_2 or SO_3, and 17% oxygen, with small amounts of CO_2 and H_2O. This atmosphere produces failure in most single phase copper-aluminium alloys by a combination of accelerated attack at temperature, and solution of the scale by condensate during shut down time. The latter, therefore, continually exposes fresh metal surfaces, leading to exfoliation of the layered scale.

The advantage of Narglas " B," therefore, is its ability to form, under these and similar conditions, an exceptionally strong adherent oxide film capable of resisting attack of this nature. This oxide film has been found to be self-healing in cases of damage to the surface.

In order to obtain optimum physical properties, Narglas " B " is heat treated, the final treatment being carried out immediately prior to tube straightening.

The information concerning the mechanical properties at normal and elevated temperatures is given in Tables I, II and III.

TABLE I.—MECHANICAL PROPERTIES

Condition	Ultimate Tensile Strength Tons/sq. in.	0·1% Proof Stress Tons/sq. in.	% Elongation	Vickers Diamond Hardness
Annealed at 650° C. ..	33	18	63	90
Solution Treated at 900° C. and Fully Aged at 500° C.	42	30	19	130
Solution Treated at 900° C. plus 25% Cold Work ..	39	28	22	180

Drift Test for End Fitting: Expansion on 30° Taper—50% No Cracking. Flat as per B.S.I.: Satisfactory. Doubling showed very slight cracking at corners

TABLE II.—CREEP PROPERTIES: CREEP RUPTURE TESTS.

Condition Solution Treated ° C.	Stress Tons/sq. in.	Temperature ° C.	Life Hours	% Elongation on 2·0 in.
900	4	450	900	3·0
950	4	450	>1,000 (No failure)	0·2 (at 1,000 hours)
1,000	4	450	> 2,000 (No failure)	0·1 (at 1,000 hours)
1,000	6	450	>1,000 (No failure)	0·2 (at 1,000 hours)
950 plus 15% Cold Work	6	450	500	1·0
950 plus 30% Cold Work	6	450	200	2·0

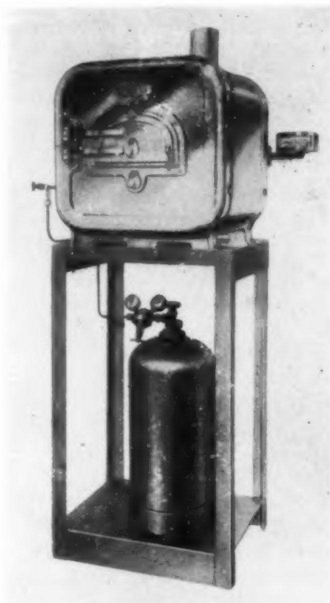
TABLE III.—CREEP PROPERTIES: CREEP TESTS.

Condition Solution Treated ° C.	Stress Tons/sq. in.	Temperature ° C.	Steady Creep Rate after 500 Hours—% per day	Total Elongation after 1,000 Hours (include Transient Creep and Elastic Extension)
900	2	450	0·008	0·40
1,000	2	450	0·001	0·14
950 plus 15% Cold Work..	2	450	0·0002	0·07

N. C. Ashton, Ltd., St. Andrews Road, Huddersfield.

Muffle Furnace

THE latest Aqualux development, a muffle furnace for use with bottled gas, attracted a good deal of attention at the British Industries Fair held recently at Castle Bromwich. There are a large number of these furnaces in service on coal gas, but the design has been modified to allow of them being fitted with Aqualux P.H.C. burners, which are suitable for burning all the modern paraffin hydrocarbon gases, such as propane and butane, generally available in this country under such trade names as Calor, Pyrogas, Bottogas, Scottish Rural Gas.



The furnaces have polished aluminium end plates and door, with a sheet steel body finished aluminium. There are two types: Type A for use up to 1,000° C., and Type B for use up to 1,250° C. The former can be fitted with fireclay, silicon-carbide, or heat-resisting steel muffles, whilst Type B furnaces are fitted with silicon-carbide muffles exclusively. For work not demanding treatment in an enclosed muffle, a refractory tray can be substituted to convert the furnace to the semi-muffle or oven type. For cupellation and other purposes, where it is essential for air to flow through, or for fumes to be exhausted from, the working chamber, muffles with a refractory vent tube connecting to the main flue outlet can be supplied. Each type is available in five sizes ranging from 6 in. × 4 in. × 3 in. high to 14¼ in. × 11½ in. × 5¾ in. high.

The very high calorific value of these gases is utilised to the full by the Aqualux P.H.C. patented burners, and temperatures difficult to obtain hitherto are now produced with ease and at a speed which is remarkable. For instance, using average calorific value fuel at 12½ lb./sq. in. pressure, the smallest Type B furnace reaches 1,000° C. in 22 minutes and 1,250° C. in 55 minutes, whilst the corresponding times for the largest size, using the same fuel at 20 lb./sq. in. pressure, are 45 minutes and 100 minutes, respectively.

Aqualux, Ltd., Emily Works, Emily Street, Birmingham, 12.

CURRENT LITERATURE

Book Notices

SYMPOSIUM ON ALUMINIUM ALLOY CASTINGS

224 pp., numerous illustrations, paper covers. The Aluminium Development Association, London, 1953. 4s.

DURING the last few years, the Aluminium Development Association has, each autumn, arranged a symposium on some aspect of light alloys. Last year, the theme was Aluminium Alloy Castings, and the papers were presented and discussed twice—in Birmingham and in London. At each centre, the Symposium was divided into two sessions with five papers in the morning and four in the afternoon. A useful discussion resulted, and the verbal contributions have been amplified in written communications: the authors' replies to the discussions have been prepared in the light of the complete contributions. The whole—papers, discussions and authors' replies have now been published by the Association in the form of a useful book.

The papers presented covered a wide range of interest within the field of aluminium alloy castings, as may be seen from their titles: "An Introduction to Aluminium Alloy Castings"; "The Importance of Standards for Aluminium Alloy Castings"; "A Survey of Some Researches on Aluminium Founding"; "Developments in Finishing Aluminium Castings"; "The Assembly of Aluminium Components by Welding"; "Recent Developments in Aluminium Foundry Practice"; "Some Interesting Aluminium Castings"; "The Design of Aluminium Alloy Castings"; and "The Future Outlook for Aluminium Castings." The last-named provides a concise summary of the present position and, at greater length, an indication of trends for aluminium castings in the various fields of application, both new and established. Through this final contribution, and, indeed, throughout the symposium as a whole, ran the theme of co-operation between aluminium founders and the users of aluminium castings, with the object of ensuring high quality products with maximum efficiency of production through a thorough understanding of the design problems involved.

STATISTICAL YEAR BOOK FOR 1951. PART II—OVERSEAS COUNTRIES

Published by the British Iron and Steel Federation, Steel House, Tothill Street, London, S.W.1. 15s.

DETAILED statistics for all the steel-producing and the most important steel-consuming industries of the world are presented in this publication. They include figures for the production of fuel, iron ore, pig iron and ferro-alloys, crude steel and finished steel, together with an analysis of the imports of raw materials and finished products according to the country of consignment, and details of the exports of the same items and their destination.

The three summary tables at the beginning of the volume give a general picture of changes in the world's iron and steel industry over a long period. World steel production recovered by 1951 to almost double the 1946 level, and was four times what it had been at the bottom of the depression of the 1930's. A similar table showing changes in hard coal production in all the principal producing countries since 1930 is given for the first time.

For the individual countries, much additional information has been included, while entirely new sections have been added for Algeria, Ceylon, Egypt, Pakistan, Rumania and Yugoslavia. These, together with additional maps, should increase the usefulness of the volume.

BRITISH STANDARDS YEARBOOK

Published by the British Standards Institution, 24, Victoria Street, London, S.W.1. 12s. 6d.

THE 1953 edition of the British Standards Handbook has just been published and gives a list of the 2,000 British Standards current at the end of March, 1953, with a brief description of the subject matter of each: a comprehensive index simplifies reference. The Yearbook gives the usual information on the membership of the General Council, the Divisional Councils and the Industry Standards Committees, together with the names of the representatives on the main Special Committees and Advisory Committees. For the first time a list is given of the British Standards under which the Institution's certification trade marks are used, whilst particulars of the work in hand of all the Industry Standards Committees are also given. The Yearbook is essential to all those engaged in industry and commerce if they are to keep up-to-date with the increasing momentum of practical standardization and simplification.

Trade Publications

Considerable progress has been made in the development of permanent magnets during the last twenty years. The introduction of Alnico was followed by the development of anisotropic alloys which led to the introduction of the Alcomax alloys. A new leaflet issued by Swift Levick & Sons, Ltd., announces the commercial availability of a new permanent magnet material, Columax, which possesses the highest magnetic energy per unit volume yet achieved in commercial magnetic alloys. It is an improved grade of Alcomax III which is cast in such a way that columnar crystals are developed with the same orientation as the preferred axis of magnetisation. This calls for a complicated technique in the foundry and Columax can only be obtained in simple shapes.

THE chromium diffusion process is a comparative newcomer among surface treatments for iron and steel, and an informative leaflet on the subject has been issued by Diffusion Alloys, Ltd., London Bridge House, S.E.1. It results in an intercrystalline penetration of chromium into the surface of iron and thereby increases its resistance to corrosion, thermal oxidation and wear. The leaflet gives the answers to a number of questions concerning the process and the product, and classified lists indicate the type of service for which the treatment is beneficial.

IN a brochure with the title: "All in the Day's Work . . .", The British Oxygen Company outlines its activities, and those of some of its associated companies,

in engineering, textiles, food, transport, farming, fishing, medicine, etc. Particular attention is directed to the industrial division, the medical division, and the chemicals division. The last-named is the most recent B.O.C. enterprise, and its interests lie in chemicals based on raw materials produced by the Group—cyanamide, dicyanamide, melamine, vinylysynolidone, polyvinylacetate, etc.

In many industrial premises, the surface wiring system is required to possess a high degree of resistance to moisture and corrosion if electrical failures are to be eliminated. A system designed to operate in such conditions is described in a booklet recently issued by British Insulated Callender's Cables, Ltd. It includes non-metal sheathed cables and all-insulated junction boxes and fittings. Properly installed, it is completely watertight and virtually proof against fumes and corrosion, and it is recommended for use in chemical works, paper mills, bleach and dye works, laundries, breweries and similar situations.

The conventional method of pack carburising was for many years the only method available for case-hardening of steel parts. Modern trends favour gas carburising, in which the pieces to be carburised are loaded on to a tray or jig which is then placed in a furnace heated by radiant tube elements. In most cases the pay load in gas carburising is 80% of the gross load, and considerable saving in fuel, floor space and labour is achieved, while carburising costs may be reduced to less than 30% by comparison with pack carburising. Moreover the precise control which can be exercised over all phases of the process results in a more uniform product. In a recent brochure, V 25, The Incandescent Heat Co., Ltd., of Smethwick, describe the process and present a series of illustrations showing different types of furnaces designed for carrying out the gas carburising operation.

Within 20 years of the opening in 1934 of the new Central Research Department of The United Steel Companies, Ltd., of Stocksbridge, a new block of laboratories four times as big as the old one has had to be built at Rotherham to accommodate the growing needs of the Research and Development Department. An account of the Swinden Laboratories and the work of the Research and Development Department is contained in an illustrated brochure recently published by the Company.

To celebrate the completion of 25 years with the 600 Group of Companies, K. and L. Steelfounders and Engineers, Ltd., of Letchworth, have issued an interesting illustrated booklet which outlines the organisation of the firm and shows the changes which have taken place since 1928. The Kryn and Laby Metal Works, Ltd., was started in 1915 by two Belgian industrialists to employ Belgian refugees from the steelfounding and engineering districts of Liege and Charleroi in support of the British war effort. A magnificent job of work was done during the first World War, but the works had virtually no stable peace-time product and for the next 10 years led a hand to mouth existence, until in 1928 the Company went into liquidation and was acquired by George Cohen's. In its early years as a member of the 600 Group, progress was extremely slow, due to the disastrous slump of 1930-33, but since that time the Company has steadily advanced, until to-day its steel foundry is one of the three or four biggest in the British Isles, and the Engineering Division is the largest producer of diesel mechanical mobile cranes in the country.

An Incandescent Heat Co. leaflet, V 26, gives the sizes of Incandescent standard gas-fired furnaces suitable for treatments in the range 600° C. to 1,000° C. The working chambers range from 12 in. long by 12 in. wide by 9 in. high for the smallest size to 48 in. by 36 in. by 18 in. for the largest size.

A new catalogue issued by Newman Industries, Ltd., Yate, Bristol, gives illustrations, dimensions and output tables for the range of Newman drip-proof slip-ring and squirrel cage motors up to 200 h.p. Full advantage has been taken of the very latest types of insulation, cooling devices and modern manufacture processes, thereby producing exceedingly efficient motors within the limits specified by B.S.168 : 1936.

The latest addition to the Newman range of electric motors is the totally-enclosed, fan-cooled, squirrel cage, foot-mounted motor with outputs from ½ h.p. to 25 h.p., to the draft B.S.CN(ELE)6814. Copies of the leaflet dealing with this range can be obtained from Newman Industries, Ltd., Yate, Bristol.

We have received from L. Light & Co., Ltd., Poyle Trading Estate, Colnbrook, Slough, a copy of their 1953 list of fine organic chemicals, which contains over 2,300 items, many of which have not previously been available to research workers. A copy will be sent on request to the Company.

Books Received

"Radioactive Isotopes" (An introduction to their preparation, measurement and use). By W. J. Whitehouse and J. L. Putman. With a foreword by J. D. Cockcroft. 424 pp. inc. author and subject indices and numerous illustrations. Oxford, 1953, at the Clarendon Press. 50s. net.

"Dislocations and Plastic Flow in Crystals." By A. H. Cottrell. 223 pp. inc. author and subject indices and numerous illustrations. Oxford, 1953, at the Clarendon Press. 25s. net. (In U.K. only).

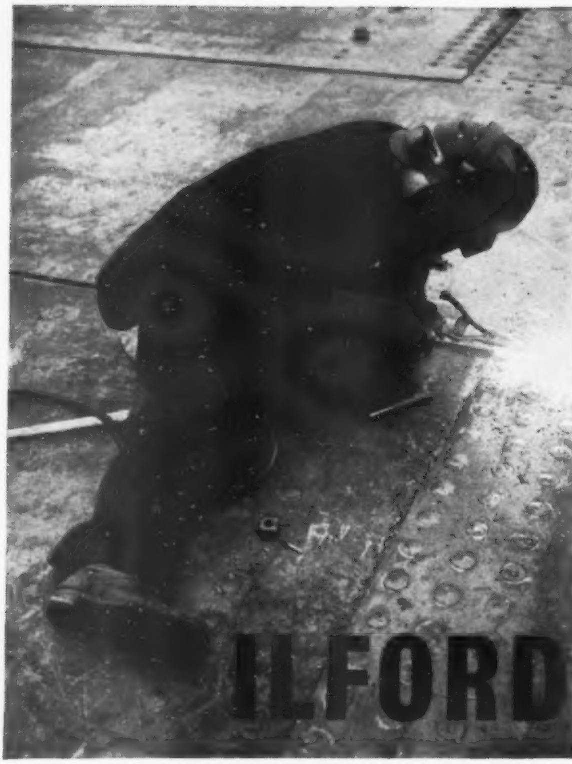
B.I.M.C.A.M. Handbook, 1953. Foreword by W. G. Ardley. 133 pp. London, 1953. The British Industrial Measuring and Control Apparatus Manufacturers' Association.

"Corrosion"—A Series of Papers Reprinted from *Research*, Vol. 5, 1952. 60 pp. London, 1953. Butterworths Scientific Publications, Ltd. 6s. net. By post 6d. extra.

The Instrument Manual. Second edition. 628 pp. inc. index. London, 1953. United Trade Press, Ltd. 84s. post free.

Proceedings of a Conference on Foundry Sands, September-October, 1949. 150 pp. Alvechurch, 1953. The British Cast Iron Research Association. 15s. to members of the Association, 18s. to non-members.

Proceedings of a Conference on Fuel in the Foundry, April, 1949. 167 pp. Alvechurch, 1953. The British Cast Iron Research Association. 15s. to members of the Association, 18s. to non-members.



All the skill and experience in the world cannot guarantee a perfect weld. The only way to be sure that the job is sound is to "look into it" with an X-ray eye. But even radiographic inspection is of little avail unless the sensitised material used is capable of recording every significant detail. This amounts to saying that here, as with other applications of radiography in the field of engineering, ILFORD Industrial X-ray films are indispensable.

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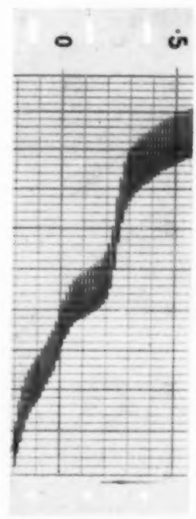

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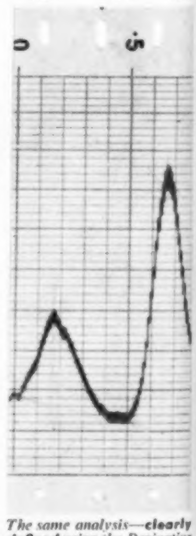

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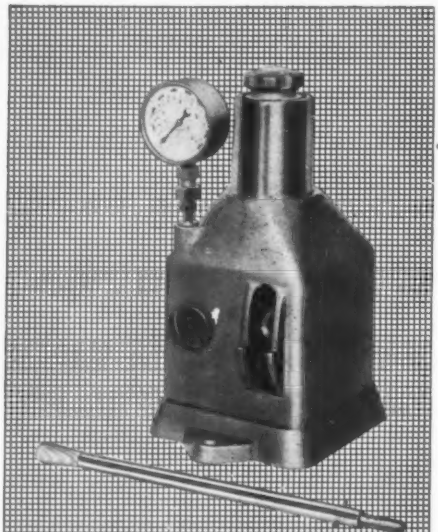

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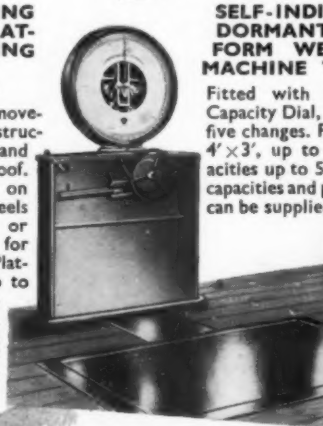

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INSTRUMENTS AND MATERIALS

JULY, 1953 Vol. XLVIII, No. 285

Use of the Ferric-Ferrous System as a Cathode Potential Regulator in the Electrolytic Separation of Silver from Baser Elements

By George Norwitz*

IT is known that oxidation-reduction systems such as Fe^{+++}-Fe^{++} can prevent the electrodeposition of certain metals[1], but no use seems to have been made of this phenomenon. In this paper it will be shown how silver can be separated from baser metals by electrolysing from a dilute nitric acid solution or a dilute nitric-phosphoric acid solution containing 5 g. of iron. The oxidation potential of the Fe^{+++}-Fe^{++} system is $+0{\cdot}76$ volt. As long as an excess of ferric ion is present, the cathode potential cannot become more negative than $+0{\cdot}76$ volt. Consequently, no element with a deposition potential more negative than $+0{\cdot}76$ volt will deposit. The deposition potential of silver is $+0{\cdot}80$ volt, and the only common metals that will deposit with it are mercury, gold, selenium and tellurium. From a nitric acid solution containing 5 g. of iron, silver can be separated from copper, bismuth, lead, arsenic, cadmium, manganese, aluminium, chromium, zinc, nickel, cobalt, and, of course, iron. Tin and antimony interfere because they precipitate as insoluble metastannic and antimonic acids, but if phosphoric acid is present to complex the tin and antimony[2] the silver can also be separated from these two elements. The maximum amount of bismuth or lead that may be present when depositing silver from a phosphoric-nitric acid solution is 0·007 g. If more than this amount is present, insoluble bismuth and lead phosphates form.

The silver deposits obtained from a nitric acid solution containing 5 g. of iron, or a nitric-phosphoric acid solution containing 5 g. of iron, are bright and adherent, whereas deposits obtained from similar solutions not containing iron are dull and non-adherent.

TABLE I.—ELECTRODEPOSITION OF SILVER FROM NITRIC ACID SOLUTIONS CONTAINING 5 GRAMS OF IRON.

Silver Present (gram)	Other Elements Present (gram)	Silver Found (gram)
0·1000	—	0·1002
0·2000	—	0·1998
0·3000	—	0·3001
0·1000	0·2 Cu	0·1001
0·2000	0·2 Cu	0·2002
0·3000	0·2 Cu	0·2998
0·1000	0·1 Bi	0·1000
0·2000	0·1 Bi	0·2002
0·3000	0·1 Bi	0·3002
0·1000	0·1 Pb	0·0998
0·3000	0·1 Pb	0·3003
0·1000	0·05 As	0·0998
0·2000	0·05 As	0·1999
0·3000	0·05 As	0·2997
0·2000	0·1 Cd+0·1 Mn+0·1 Al	0·2002
0·2000	0·1 Cr.+0·1 Zn+0·1 Ni +0·1 Co	0·2001

TABLE II.—ELECTRODEPOSITION OF SILVER FROM NITRIC-PHOSPHORIC ACID SOLUTIONS CONTAINING 5 GRAMS OF IRON.

Silver Present (gram)	Other Elements Present (gram)	Silver Found (gram)
0·1000	—	0·0998
0·2000	—	0·1999
0·3000	—	0·3003
0·1000	0·2 Cu	0·1001
0·2000	0·2 Cu	0·2002
0·3000	0·2 Cu	0·2997
0·1000	0·1 Sn	0·1002
0·2000	0·1 Sn	0·2002
0·3000	0·1 Sn	0·2998
0·1000	0·1 Sb	0·1002
0·2000	0·1 Sb	0·2002
0·3000	0·1 Sb	0·2997
0·1000	0·05 As	0·0998
0·3000	0·05 As	0·3000
0·1000	0·007 Bi	0·1002
0·3000	0·007 Bi	0·3002
0·1000	0·007 Pb	0·0999
0·3000	0·007 Pb	0·3001
0·2000	0·1 Cd+0·1 Mn+0·1 Al	0·2000
0·2000	0·1 Cr+0·1 Zn+0·1 Ni +0·1 Co	0·2004

Experimental

A standard silver solution was prepared by dissolving 4·0000 g. of pure silver in 50 ml. of nitric acid (1 to 1) and diluting to 1 litre in a volumetric flask.

Five gram portions of pure iron (National Bureau of Standards Sample 55b) were dissolved in 200-ml. electrolytic beakers with 50 ml. of nitric acid (1 to 1) by heating on the hot plate. Aliquots of standard silver solution and aliquots of standard solutions of other metals were added and the volumes brought up to about 170 ml. The solutions were electrolysed for 1 hour at 2 amp./sq. dm. using platinum gauze cathodes and platinum spiral anodes. The electrolyses were conducted at room temperature and the solutions were stirred. After electrolysis was completed, the cathodes were immersed in water and in alcohol, dried at 110° C. for a few minutes, cooled, and the deposits weighed as metallic silver. The results obtained are shown in Table I.

Five grams of pure iron (National Bureau of Standards Sample 55b) were dissolved in 200-ml. electrolytic beakers with 50 ml. of nitric acid (1 to 1) by heating on the hot plate. Ten millilitres of phosphoric acid (85%) were added, followed by aliquots of standard silver solution and aliquots of standard solutions of other elements, and the silver electrolysed as described above. The results obtained are shown in Table II.

* Laboratory of George Norwitz, 3353 Ridge Avenue, Philadelphia, Pa.

1 Rodden, C. J. "Analytical Chemistry of the Manhattan Project," pp. 518, 519, New York, McGraw-Hill Book Co., 1950.

2 Norwitz, G. *Analytical Chemistry*, **21**, 523 (1949).

A Method of Illumination for the Photography of Markings on Large Flat Areas of Sheet*

By A. Loro, B.Sc.

(A Communication from the British Non-Ferrous Metals Research Association)

IN the course of a study of stretcher-strain markings on aluminium alloy sheet, it was desired to photograph the markings which had been produced by stretching strips 8 in. $\times$ 1¼ in. in size and ordinary sheet tensile specimens part-way through the initial large yield[1]. This was successfully accomplished by the Schlieren-type technique described here, although the usual methods of illumination for macro-photography had proved quite unsuitable. The difficulty lay in the fact that the specimens were made up of small mirror-like regions tilted with respect to one another at angles varying from 1′ to 30′, so that a critical angle of lighting and viewing was necessary in order to see a boundary between two regions, and it was not generally possible to see all the boundaries simultaneously with the naked eye with any one position of viewing. The method of illumination described would be suitable for the macro-photography of somewhat larger areas, providing that they were truly flat apart from the markings or other features which it is desired to observe. Any regions of the surface which deviate from planeness photograph in dark contrast to the rest.

Details of the Method

Fig. 1 gives a general indication of the arrangement, and for convenience in the description which follows, the plane of the diagram will be considered to be horizontal. A cylindrical mirror *AB* forms an image of a vertical slit source *S*, so that the image is coincident with the slit, at the centre of curvature of the mirror. A plane glass plate *CD* turns some of the reflected light through 90°, and this light is again reflected at the specimen *FE*, coming to a focus at *G* on the camera lens.

A perfectly flat polished specimen appears evenly illuminated over its whole surface when viewed from the camera position under these conditions, since each part of the surface reflects all the incident light into the image of the slit formed at *G*. Any local change in surface direction results in light from that part of the surface falling to one side of *G* and, if the change is sufficiently great, outside the camera lens.

Sensitivity

The sensitivity of the system increases with decreasing slit width and camera aperture, the limit being set in practice by the accuracy of the cylindrical mirror and the overall flatness of the specimen. A cylindrical mirror with a slit source was adopted in preference to a spherical mirror and point source, because of the ease with which such a mirror, sufficiently large and accurate for the requirements, can be constructed. It results in much greater sensitivity to surface rotation about a

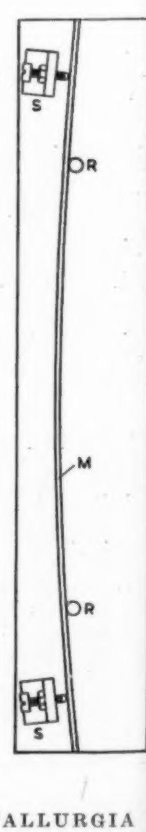

Fig. 2—Construction of cylindrical mirror.

* B.N.F.M.R.A. Report T.M. 108P.

[1] V. A. Phillips, A. J. Swain and R. Eborall, *J.Inst. Metals*, 1952–3, **81** (*In the Press*).

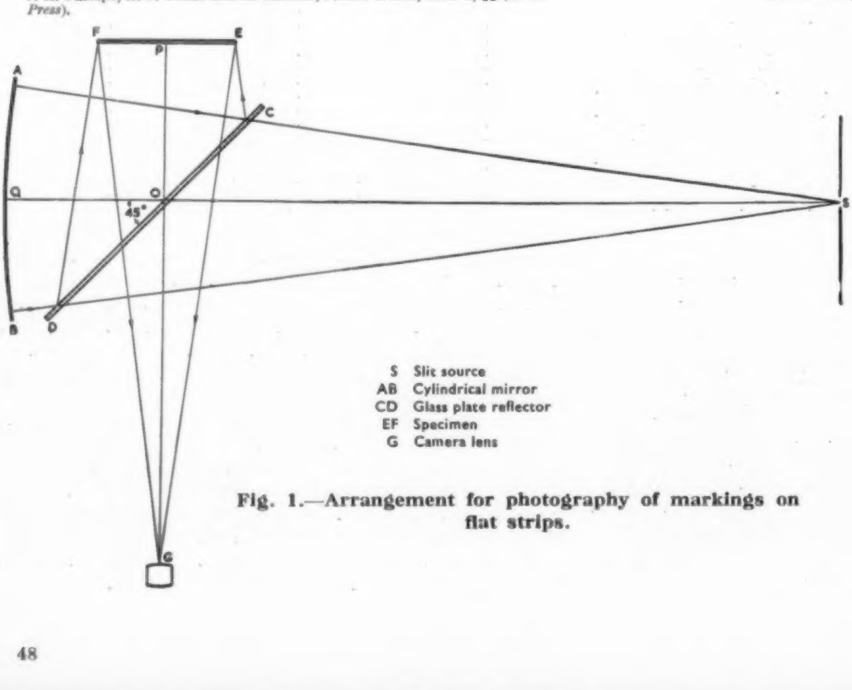

Fig. 1.—Arrangement for photography of markings on flat strips.

vertical axis than about a horizontal one, but this is no disadvantage for the present purpose.

With the aluminium mirror to be described, and a source 7 in. $\times \frac{1}{2}$ in. in size, markings due to angular changes of 3 to 5 minutes of arc were boldly shown and secondary markings within the yielded areas of the specimen, believed to be due to much smaller angular changes, were also clearly shown.

Construction of the Mirror

A satisfactory mirror can be constructed from a strip of polished aluminium sheet by bending it elastically with a uniform bending couple in a simple jig (Fig. 2). The mirror used was made from a strip of aluminium—$3\frac{1}{2}$% magnesium sheet 0·045 in. thick and measuring $3\frac{1}{2}$ in. $\times$ 24 in. It was bowed against two $\frac{3}{8}$ in. diameter vertical brass rods *RR*, fixed rigidly in a wooden base board 1·5 in. apart. Pressure was applied at points 3 in. from the rods by means of 4 B.A. bolts screwed through brass brackets *SS* fixed to the base board. Radii of curvature down to 40 in. were easily obtained in this manner and were well within the elastic limit of the material.

Adjustment and Testing of Mirror

The radius of curvature required is determined mainly by the camera-to-specimen distance to be used. The radius must be equal to this distance plus the sum of the distances from the 45° reflector to the mirror and to the specimen ($GP + PO + OQ$ in Fig. 1). To adjust the mirror it has been found convenient to use a vertical slit, about $\frac{1}{2}$ in. wide, in a white card placed in front of a pearl lamp with a diffuser of ground glass or tracing paper between lamp and card. The slit is set up at the desired distance from the mirror and the curvature of the mirror adjusted by equal tightening or slackening of the bolts at each end until the best image of the slit is thrown on the white card close beside the slit.

The accuracy of curvature of the mirror may be assessed by viewing the mirror from the position of the slit image. This is achieved by placing a sheet of plane glass 45° to the beam, about 6 in. in front of the slit, and viewing the reflection of the mirror from the new position of the slit image (Fig. 3). When so viewed, the mirror should appear flooded with light over the full aperture between the brass rods and, if the slit is long enough, over its full height.

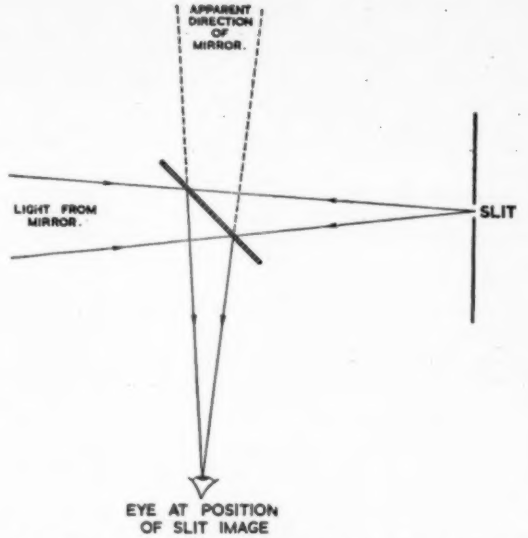

Fig. 3.—Use of additional glass plate reflector for focussing mirror.

The Illuminant and Exposure

For photography, a safelight illuminator fitted with a 150 watt lamp was found satisfactory, the safelight screen being replaced by a black card with a vertical slot 7 in. $\times \frac{1}{2}$ in. in size. Using a radius of curvature of

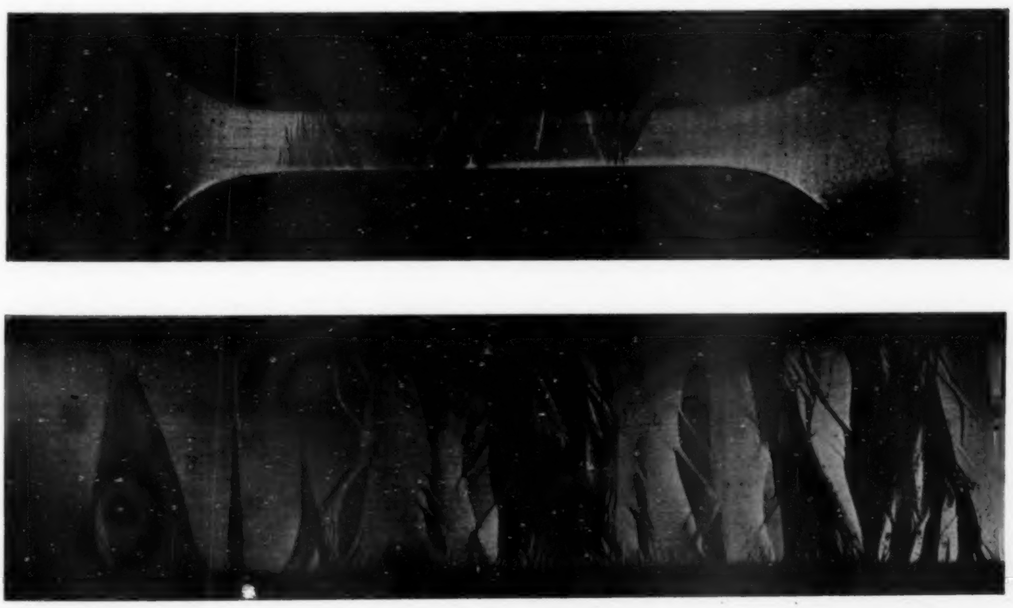

Fig. 4.—Examples of stretcher-strain markings in aluminium alloy sheet, photographed by the method described.

48 in., and a 10 in. lens 30 in. from the specimen stopped down to F11, exposures of the order of 10–20 sec. on Ilford Chromatic plates gave satisfactory photographs of highly polished specimens. When the angles of the boundaries of the markings amounted to 20′–30′, a ½ in. slit tended to give excessive contrast which was reduced by widening the slit and increasing the lens aperture.

Although the slit should be at or near the centre of curvature of the mirror in order to avoid spherical aberration, in practice, final adjustment of the illumination was most conveniently carried out by small lateral movements of the slit.

If the camera lens is in the position indicated in Fig. 1, an image of the slit is seen in the direction of the specimen but located some distance behind it due to reflection in the 45° reflector. This may be avoided by raising or lowering the camera position until the slit image and specimen images are separated on the ground glass screen, the specimen being rotated about a longitudinal axis to bring the convergent beam back into the lens. The resulting distortion of the specimen image is small and is readily corrected by the usual camera adjustments.

Photography is best carried out in a darkened room in order to avoid stray reflections in the specimen and 45° reflector, and to facilitate the adjustment of the optical system.

Fig. 4 shows examples of the photographs obtainable by this method of illumination.

Acknowledgements

The author thanks the Director and Council of the British Non-Ferrous Metals Research Association for permission to publish this paper.

Determination of the Orientation of Single Crystals of Titanium

By A. T. Churchman, B.Sc., Ph.D.

A.E.I. Research Laboratory, Aldermaston.

USING the back reflection Laue technique, suitable films can be obtained from single crystals of titanium using copper radiation at 45 kV. The fluorescent radiation emitted by the titanium specimen is absorbed by an aluminium foil placed in front of the film.

It is essential, in interpreting these films, to have available a standard plot of the lattice and a table of possible angles between crystallographic planes of low indices in this lattice. While these are readily available for cubic lattices[1], the fact that the angles vary with the c/a ratio of the lattice has prevented the issue of comprehensive tables for crystals of hexagonal structure. An incomplete table has been published[2] for titanium based on the lattice parameters given by Clark[3] ($c/a = 1{\cdot}587$). The accompanying Table I gives all the possible angles between the 13 planes of lowest indices in a hexagonal lattice with $c/a = 1{\cdot}591$, which appears to be the best value from published data[2-6] for titanium. These planes include all the reported slip (0001) ($10\bar{1}0$) ($10\bar{1}1$) ($11\bar{2}0$) and twinning ($10\bar{1}2$) ($11\bar{2}1$) ($11\bar{2}2$) elements for titanium.

It is also useful to include in the standard plot the six planes of the type given in Table II as they give reflections of similar intensity to $\{10\bar{1}0\}$.

Further, due to the lower order of symmetry of the hexagonal lattice, compared with the cubic lattice, several of the principal zone axes have irrational indices. As the interpretation of the orientation from the Laue films involves plotting zone axes[1] on the stereographic projection, it is necessary to include all the principal zone axes in the standard projection to avoid ambiguity in interpretation. The zones corresponding to the axes tabulated in Table III are those which appear most frequently in back reflection photographs of titanium.

Using values of $c/a = 1{\cdot}591 \pm 0{\cdot}004$, instead of $c/a = 1{\cdot}591$, results in angular differences, depending on the particular pair of planes, of from 0 to 40′ of arc; this variation is within the experimental error of the back reflection technique. The variation of c/a with oxygen and nitrogen content of the titanium up to 6 atomic per cent. (approximately 2 wt. per cent.) lies within these limits[6], as also does the value recently reported for oxygen-free zirconium[7]. The tables are therefore applicable to both iodide and Kroll titanium and zirconium.

The author wishes to thank Dr. G. A. Geach, Leader of the Physical Metallurgy Section of the A.E.I. Research Laboratory, for encouragement and helpful discussion; he also wishes to express his thanks to Dr. T. E. Allibone, F.R.S., for permission to publish this work.

TABLE I.

$$\cos\phi = \frac{Hh + Kk + \tfrac{1}{2}(Hk + Kh) + \tfrac{3}{4}\frac{a^2}{c^2}Ll}{\sqrt{\left(H^2+K^2+HK+\tfrac{3}{4}\frac{a^2}{c^2}L^2\right)\left(h^2+k^2+hk+\tfrac{3}{4}\frac{a^2}{c^2}l^2\right)}}$$

HKL	hkl	Possible values of ϕ					
0001	0001	180°					
	$10\bar{1}0$	90°					
	$10\bar{1}1$	61° 27′					
	$10\bar{1}2$	42° 34′					
	$10\bar{1}3$	31° 39′					
	$11\bar{2}0$	90°					
	$11\bar{2}1$	72° 33′					
	$11\bar{2}2$	58° 01′					
	$11\bar{2}3$	46° 41′					
	$11\bar{2}4$	38° 30′					
	$21\bar{3}0$	90°					
	$21\bar{3}1$	78° 22′					
	$20\bar{2}1$	75° 22′					
$10\bar{1}0$	$10\bar{1}0$	60°	120°	180°			
	$10\bar{1}1$	28° 34′	63° 57′	116° 03′	151° 26′		
	$10\bar{1}2$	47° 26′	70° 14′	109° 46′	132° 34′		
	$10\bar{1}3$	58° 31′	74° 52′	105° 08′	121° 29′		
	$11\bar{2}0$	30°	90°	150°			
	$11\bar{2}1$	34° 18′	90°	145° 42′			
	$11\bar{2}2$	42° 51′	90°	137° 09′			
	$11\bar{2}3$	50° 57′	90°	129° 03′			
	$11\bar{2}4$	57° 22′	90°	122° 38′			
	$21\bar{3}0$	19° 07′	40° [illegible]	79° 06′	100° 54′	139° 06′	160° 53′
	$21\bar{3}1$	22° 15′	42° [illegible]4′	79° 20′	100° 40′	137° 46′	157° 45′
	$20\bar{2}1$	15° 14′	61° 09′	118° 51′	164° 46′		

TABLE I (*Continued*)

HKL	hkl	Possible values of ϕ					
$10\bar{1}1$	$10\bar{1}1$	52° 06′	99° 02′	122° 53′	180°		
	$10\bar{1}2$	18° 53′	49° 31′	86° 51′	104°		
	$10\bar{1}3$	29° 57′	50° 26′	79° 43′	92° 55′		
	$11\bar{2}0$	40° 29′	90°	139° 31′			
	$11\bar{2}1$	81° 46′	29° 40′	125° 37′			
	$11\bar{2}2$	26° 03′	75° 16′	112° 56′			
	$11\bar{2}3$	70° 51′	28° 12′	103° 02′			
	$11\bar{2}4$	32° 03′	68° 02′	173° 30′			
	$21\bar{3}0$	33° 54′	48° 24′	80° 27′	99° 33′	131° 36′	146° 06′
	$21\bar{3}1$	24° 36′	41° 42′	75°	93° 48′	123° 32′	135° 46′
	$20\bar{2}1$	13° 19′	56° 41′	107° 09′	136° 13′		
$10\bar{1}2$	$10\bar{1}2$	39° 32′	71° 44′	85° 08′	180°		
	$10\bar{1}3$	11° 07′	36° 26′	63° 10′	74° 03′		
	$11\bar{2}0$	54° 08′	90°	125° 52′			
	$11\bar{2}1$	38° 46′	77° 15′	109° 46′			
	$11\bar{2}2$	27° 23′	66° 57′	95° 58′			
	$11\bar{2}3$	21° 21′	59° 39′	85° 28′			
	$11\bar{2}4$	19° 47′	54° 48′	102° 13′			
	$21\bar{3}0$	50° 16′	59° 15′	82° 39′	97° 21′	120° 45′	129° 34′
	$21\bar{3}1$	39° 15′	49° 31′	74° 07′	90° 08′	110° 38′	118° 32′
	$20\bar{2}1$	32° 13′	58° 43′	97° 38′	117° 20′		
$10\bar{1}3$	$10\bar{1}3$	30° 16′	53° 47′	62° 58′	180°		
	$11\bar{2}0$	63°	90°	117°			
	$11\bar{2}1$	46° 36′	75° 11′	100° 07′			
	$11\bar{2}2$	33° 12′	63° 01′	85° 56′			
	$11\bar{2}3$	23° 52′	54° 11′	75° 11′			
	$11\bar{2}4$	18° 23′	48° 08′	67° 18′			
	$21\bar{3}0$	60° 21′	66° 41′	95° 41′	84° 19′	113° 19′	119° 39′
	$21\bar{3}1$	41° 15′	49° 04′	56° 03′	94° 19′	102° 24′	108° 15′
	$20\bar{2}1$	43° 17′	61° 35′	91° 36′	106° 15′		
$11\bar{2}0$	$11\bar{2}0$	60°	120°	180°			
	$11\bar{2}1$	17° 27′	61° 31′	118° 29′	162° 33′		
	$11\bar{2}2$	31° 59′	64° 54′	115° 06′	148° 01′		
	$11\bar{2}3$	43° 19′	68° 40′	111° 20′	136° 41′		
	$11\bar{2}4$	51° 30′	71° 52′	108° 08′	128° 30′		
	$21\bar{3}0$	10° 54′	49° 06′	70° 53′	109° 07′	130° 07′	169° 06′
	$21\bar{3}1$	23° 26′	52° 17′	72° 11′	107° 49′	127° 43′	156° 34′
	$20\bar{2}1$	33° 33′	90°	146° 27′			
$11\bar{2}1$	$11\bar{2}1$	56° 59′	111° 25′	145° 06′	180°		
	$11\bar{2}2$	14° 43′	55° 43′	104° 04′	130° 24′		
	$11\bar{2}3$	25° 53′	56° 27′	98° 08′	119° 14′		
	$11\bar{2}4$	34° 03′	57° 53′	93° 34′	111° 03′		
	$21\bar{3}0$	20° 29′	51° 21′	71° 48′	108° 12′	128° 39′	159° 31′
	$21\bar{3}1$	12° 03′	47° 46′	68° 31′	104° 13′	123° 27′	149°
	$20\bar{2}1$	28° 51′	85° 29′	135° 56′			
$11\bar{2}2$	$11\bar{2}2$	49° 58′	94° 20′	115° 46′	180°		
	$11\bar{2}3$	11° 11′	47° 42′	93° 19′	104° 32′		
	$11\bar{2}4$	19° 21	47° 10′	81° 12′	96° 27′		
	$21\bar{3}0$	33° 41	56° 18′	73° 54′	106° 06′	123° 32′	146° 19′
	$21\bar{3}1$	22° 54	49° 27′	67° 45′	99° 27′	115° 50′	135°
	$20\bar{2}1$	32° 06′	81° 59′	124° 35′			
$11\bar{2}3$	$11\bar{2}3$	42° 40′	88° 19′	93° 22′	180°		
	$11\bar{2}4$	8° 13′	40° 15′	71° 53′	88° 19′		
	$21\bar{3}0$	44° 24′	61° 33′	76° 13′	103° 47′	118° 27′	135° 36′
	$21\bar{3}1$	33° 04′	52° 47′	68° 11′	95° 27′	109° 10′	124° 10′
	$20\bar{2}1$	37° 59′	79° 37′	115° 20′			
$11\bar{2}4$	$11\bar{2}4$	36° 16′	65° 15′	77°	180°		
	$21\bar{3}0$	52° 17′	65° 51′	78° 15′	101° 45′	114° 09′	127° 43′
	$21\bar{3}1$	42°	56° 10′	69° 04′	103° 58′	92° 24′	116° 10′
	$20\bar{2}1$	43° 28′	78° 08′	108° 21′			
$21\bar{3}0$	$21\bar{3}0$	21° 47′ / 141° 47′	38° 13′ / 158° 13′	60° / 180°	81° 47′	98° 13′	120°
	$21\bar{3}1$	11° 38′ / 119° 19′	24° 34′ / 140° 19′	39° 41′ / 155° 26′	60° 41′ / 168° 22′	81° 57′	98° 03′
	$20\bar{2}1$	24° 15′	43° 10′	79° 30′	100° 30′	136° 50′	155° 45′
$21\bar{3}1$	$21\bar{3}1$	21° 20′ / 142° 36′	37° 24′ / 158° 40′	58° 39′ / 180°	79° 46′	100° 14′	121° 21′
	$20\bar{2}1$	18° 56′	39° 53′	76° 37′	97° 13′	131° 25′	147° 09′
$20\bar{2}1$	$20\bar{2}1$	57° 41′	113° 22′	149° 33′	180°		

TABLE II.—DATA FOR PLOTTING EXTRA PLANES GIVING SAME RELATIVE INTENSITY REFLECTIONS AS $\{10\bar{1}0\}$

	$\langle 11\bar{2}0 \rangle$ zone				$\langle 10\bar{1}0 \rangle$ zone	
Angles between	$\{30\bar{3}2\}$	$\{20\bar{2}3\}$	$\{10\bar{1}4\}$	$\{10\bar{1}5\}$	$\{11\bar{2}6\}$	$\{11\bar{2}8\}$
$\{10\bar{1}0\}$	19° 55′	39° 14′	65° 23′	69° 59′	—	—
$\{11\bar{2}0\}$	—	—	—	—	62° 04′	68° 18′
(0001)	70° 05′	50° 46′	24° 37′	20° 01′	27° 56′	21° 42′

TABLE III.
DATA FOR PLOTTING ZONE AXES OF IRRATIONAL INDICES.

Zone on which axis lies	Degrees from			Remarks
	(0001)	$\{1\bar{1}00\}$	$\{11\bar{2}0\}$	
$\langle 0001 \rangle$	—	10° 59′	19° 07′	Corresponds to $(\bar{4}5\bar{1}0)$ Occurs very frequently
$\langle 11\bar{2}0 \rangle$	47° 26′	42° 34′	—	Occurs very frequently
$\langle 10\bar{1}0 \rangle$	31° 59′ 51° 30′ 17° 27′	58° 01′ 38° 30′ 72° 33′	— — —	Frequent Fairly frequent Fairly frequent
$\langle 21\bar{3}0 \rangle$	59°	31° from $(\bar{4}5\bar{1}0)$	—	Fairly frequent

REFERENCES.

1 C. S. Barrett. "Structure of Metals," McGraw Hill Publishing Co., New York, 1952, p. 36 (also 1943, p. 35).
2 C. J. McHargue. *J. of Metals*, 1952, **4**, 660.
3 H. T. Clark. *Trans. A.I.M.M.E.*, 1949, **185**, 588.
4 E. C. Greiner and W. C. Ellis. *Trans. A.I.M.M.E.*, 1949, **180**, 657.
5 B. Gonser. U.S. Off. Naval Res. Conf. on Titanium, 1948, Washington, 1949, p. 66.
6 W. Rostoker. *J. of Metals*, 1952, **4**, 987.
7 R. M. Treco. *J. of Metals*, 1953, **5**, 345.

Significance of Anodic Current Density

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The volumes were brought up to about 170 ml. and the solutions electrolysed for 1 hour using platinum gauze cathodes and platinum spiral anodes. The electrolyses were conducted at room temperature, using a variety of currents, and the solutions were stirred. The results obtained for lead and manganese, after stripping the deposits in a mixture of nitric acid and hydrogen peroxide, and determining the lead as lead sulphate and the manganese colorimetrically, are shown in Table II. Also included in Table II are results obtained for lead when the deposits were weighed as lead dioxide. It is seen from Table II that lead can be separated from up to 0·03 g. of manganese by the use of a spiral anode. The reason for the success of the separation is the extremely high anodic current density obtainable with a spiral anode. 0·0025 g. is about the maximum amount of lead that can be deposited on a spiral anode.

Analytical Chemistry Symposium, 1954

Arising from the success of the short Symposium on Analytical Chemistry held in Birmingham in 1952, it is proposed to run a larger Symposium from August 25th to September 1st, 1954. This will consist of original papers and recent advances in various analytical fields. An exhibition of new and special apparatus will be held simultaneously and visits to local places of interest will be organised. A ladies committee has been formed to organise entertainment for non-scientific visitors. Further details will be made available at a later date.

Significance of Anodic Current Density in the Electrolytic Separation of Lead Dioxide from Manganese

By George Norwitz*

A SEQUENCE procedure for the determination of copper, lead, manganese, iron, nickel, aluminium and tin in manganese bronzes was proposed by the author in an earlier paper.[1] In this procedure, the lead was deposited as lead dioxide from a perchloric-nitric acid medium using a platinum spiral as an anode. It was noted that the use of a platinum spiral prevented contamination of the lead dioxide by manganese dioxide. The reason why a spiral acted in this way was puzzling, and it was decided to investigate the phenomenon. It was finally established that the significant feature in the electrolytic separation of lead dioxide from manganese was the use of a high anodic current density. The importance of anodic current density in this connection has not previously been recognised.

Apparatus and Reagents

Platinum gauze cathodes were used which were 4·5 cm. in diameter and 5·0 cm. in height. The surface area of these cathodes, as calculated by multiplying the circumference of the wire by the total length of the wire, was 129 sq. cm. The platinum gauze anodes used were 2·5 cm. in diameter and 5·0 cm. in height, and the surface area of these gauze anodes, as calculated in the same way, was 44 sq. cm. Platinum spiral anodes were also used which were made of wire 1·1 mm. in diameter. The width of the spiral portion was 1·0 cm., and the surface area of these spiral anodes was 7·1 sq. cm.

A standard lead solution was prepared by dissolving 0·5000 g. of pure sheet lead in 20 ml. of nitric acid (1 to 1) and diluting to 1 litre in a volumetric flask.

A standard manganese solution was prepared by dissolving 1·0000 g. of high purity manganese in 15 ml. of nitric acid (1 to 1) and diluting to 1 litre in a volumetric flask.

A copper nitrate solution was prepared by dissolving 12 g. of $Cu(NO_3)_2 \cdot 5H_2O$ in 500 ml. of water.

Other reagents used were: nitric acid, sp.gr. 1·41; sulphuric acid, sp.gr. 1·84; and hydrochloric acid, 0·1 N.

Experimental

Aliquots of standard lead solution containing 0·0250 g. of lead and aliquots of standard manganese solution containing 0·0100 g. of manganese were pipetted into 200 ml. electrolytic beakers. Seven ml. of nitric acid, 1 drop of 0·1 N hydrochloric acid[2] and 20 ml. of copper nitrate solution were added and the volumes brought up to about 170 ml. The solutions were electrolysed for 1 hour, using platinum gauze cathodes and platinum gauze anodes. The electrolyses were conducted at room temperature, using a variety of currents, and the solutions were stirred. The amount of lead in the deposit was found by dissolving the deposit in a mixture of nitric acid and hydrogen peroxide, adding 2 ml. of sulphuric acid and evaporating to fumes of sulphuric acid. The lead was determined as lead sulphate in the usual manner.[3] The manganese in the deposit was determined by adding 3 ml. of nitric acid to the lead sulphate filtrate, oxidising with ammonium persulphate in the presence of silver nitrate, and titrating with arsenite[4]. The results obtained for lead and manganese are shown in Table I, from which it will be seen that the greater the anodic current density the less the tendency for manganese to deposit. Attempts to separate lead from manganese by one deposition using gauze anodes were not successful. The only safe procedure when gauze anodes are used is to deposit the lead dioxide at a high anodic current density, and dissolve the deposit in a mixture of nitric acid and hydrogen peroxide. The solution is then boiled to destroy the peroxide, the 0·1 N hydrochloric acid and copper nitrate solution are added and the lead deposited again at a high anodic current density. In handling lead dioxide deposits containing manganese dioxide, care must be taken not to rub off any of the deposit, since the presence of manganese dioxide causes the lead dioxide to be less adherent.

TABLE I.—RESULTS FOR THE SEPARATION OF LEAD DIOXIDE FROM MANGANESE USING GAUZE ANODES (0·0250 g. OF LEAD AND 0·0100 g. OF MANGANESE PRESENT)

Amperes*	Anodic Current Density (amp./sq.dm.)	Pb Found (gram)	Mn Found (gram)
0·3	0·68	0·0244	0·0051
0·6	1·36	0·0246	0·0045
1·0	2·27	0·0246	0·0038
2·0	4·54	0·0248	0·0030
2·5	5·68	0·0249	0·0022
3·0	6·82	0·0249	0·0019

* As measured across the electrodes.

TABLE II.—RESULTS FOR THE SEPARATION OF LEAD DIOXIDE FROM MANGANESE USING SPIRAL ANODES

Amperes*	Anodic Current Density (amp./sq.dm.)	Pb Present (gram.)	Mn Present (gram)	Pb Found (gram)	Mn Found (gram)
0·3	4·23	0·0025	0·01	0·0024	0·0002
0·3	"	"	0·02	0·0023	0·0005
0·3	"	"	0·03	0·0024	0·0009
1·0	14·1	"	0·01	0·0025	0·0001
1·0	"	"	0·02	0·0024	0·0003
1·0	"	"	0·03	0·0024	0·0003
2·0	28·2	"	0·01	0·0024	0·0000
2·0	"	"	0·03	0·0024	<0·0001
2·0	"	"	0·04	0·0024	0·0001
2·0	"	"	0·05	0·0023	0·0003
2·0	"	"	0·02	0·0024†	——
2·0	"	"	0·03	0·0025†	——
2·0	"	"	0·03	0·0025†	——
2·0	"	"	0·00	0·0024†	——

* As measured across the electrodes.
† Weighed as lead dioxide.

Aliquots of standard lead solution containing 0·0025 g. of lead were pipetted into 200 ml. electrolytic beakers. Various aliquots of standard manganese solution were added, followed by 7 ml. of nitric acid, 1 drop of 0·1 N hydrochloric acid and 20 ml. of copper nitrate solution.

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1 Norwitz, G., *Analyst*, **76**, 314 (1951).
2 Scherrer, J. A., Bell, R.K., and Mogerman, W.D., *J. Research National Bureau of Standards*, **22**, 697 (1939).
3 Am. Soc. for Test. Materials, "A.S.T.M. Methods of Chemical Analysis of Metals," p.201, Philadelphia, Pa., 1946.
4 Ibid., p.212.